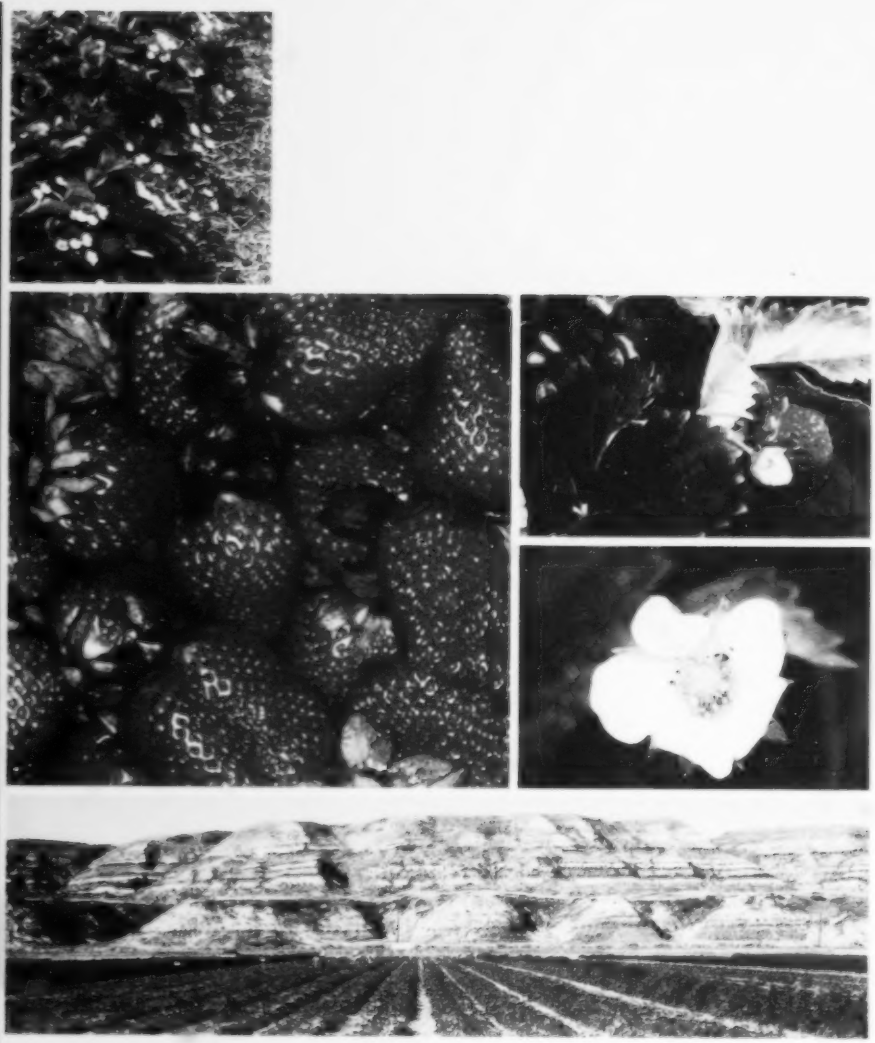
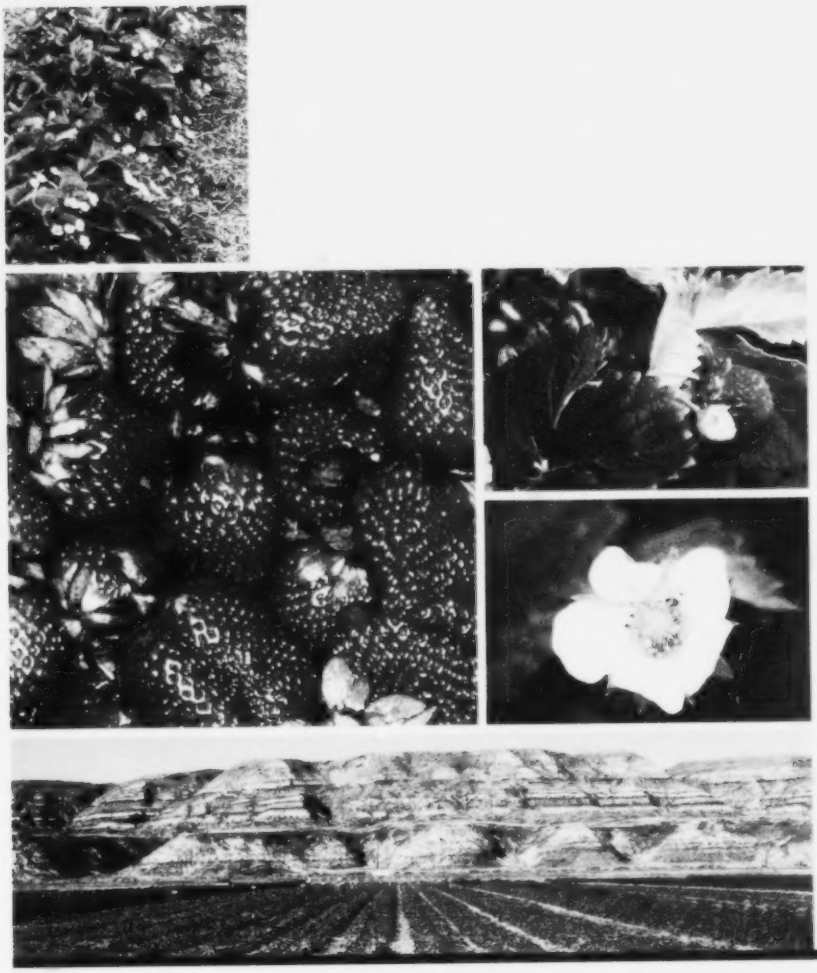


Commercial Strawberry Production

on the Prairies



Commercial Strawberry Production

on the Prairies

Alberta
AGRICULTURE, FOOD AND RURAL DEVELOPMENT

Saskatchewan
Agriculture, Food
and Rural
Revitalization

Manitoba
Agriculture, Food
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Contents

Introduction 1

Statistics 1
Purpose of the guide 1

The Strawberry Plant 2

Taxonomy and distribution 2
General biology 2
Morphology and plant development 2
The root 2
The crown 3
Development of runners 4
Flower stalk (inflorescence) 4

Preliminary Considerations 6

Site Selection 7

Soil considerations 7
Soil testing 7
Soil test reports 7
Drainage 8
Soil tilth 8
Previous crops/crop rotation 9
Water for irrigation 9
Microclimate 9
Shelterbelts 10
Permanent shelterbelts 10
Annual supplementary shelter 10

Cultivars 12

Day-neutral strawberries 12
June bearing strawberries 13
Other cultivars 14
New cultivars 14

New Plantings 15

Soil Preparation 15
Care of nursery plants before planting 16
Planting 16
Planting steps 16
Planting distance 16
Planting depth 17
Fertility management 18
Fertilizer application before or at planting 18
Fertilization after planting 18
Nitrogen 18
Phosphorus 19
Potassium 20
Sulphur 20
Calcium 21
Micronutrients 21
Plant tissue testing 21
Care of the young plant 22
Irrigation of a young planting 24
Spray program in the planting year 24
Management of runners 24

Pre-winter Care 25

Mulching 25
Straw fumigation 26

Picking Year 27

Mulch removal 27
Spring fertilizer applications 28
Pollination 28
Spray program for the picking year 28

Renovation 29

How to renovate 29

Day-neutral Strawberry Production System 31

Plant structure 31
Roots 31
Flowers 31
Day-neutral strawberry production cycle 31
Planting 31
Cropping season management 32
Fertility 32
Derunnering/deblossoming 32
Irrigation 32
Application of straw mulch 33
Post-harvest considerations 33
Other considerations 33

Irrigation 34

Strawberry-water interrelations 34
Strawberry irrigation requirements and timing 34
Determining soil moisture levels 35
Selecting an irrigation system 35
Planning an irrigation system 36
A solid set irrigation system for strawberries 36
Solid set irrigation system components 36
Economic irrigation considerations 38
Special applications of solid set irrigation 38
Radiation frost and freezing injury 38
Frost control principle and frost injury levels 39
Frost control using less water 40
Crop cooling 40
Drip Irrigation 40

Equipment for Strawberry Production 42

Tractors 42
Other equipment required 42

Marketing Strawberries 44

Drawing customers 44
Liability 44
Time to pick 45
The picking operation 45
Sales etiquette 45
Sale of picked berries 46
Amenities 46

Cost of Production 47

New Developments 48

On-farm Food Safety 49

Background 49
Program scope 49
What is in the OFFS guidelines 50
OFFS guidelines summaries 50
Premises (includes production sites) 50
Soil amendments and fertilizers 51
Agricultural chemicals 51
Water 51
Harvest containers 51
Equipment and tools 52
Transportation and storage 52
Cleaning and sanitation 52
Personal hygiene 52
Pest control 53
Product traceability 53
Accessing the OFFS guidelines for fresh fruit and vegetables 53

Pesticide Safety and Management 54

Choosing appropriate pesticide products 54
Toxicity of the chemicals 54
Proper safety equipment 54
Poisoning 55
Chemical application 55
Effectiveness of spraying 55

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Strawberry Disease and Pest Problems 56
Problem identification 56

Physiological Disorders (Abiotic, Non-infectious Diseases) 58
Disorders attributed to nutrient deficiencies 58
Tip burn 58
Yellowing or chlorosis 58
Disorders attributed to adverse environmental conditions 58
Wind damage to the foliage and fruit 58
Sunscald of fruit 59
Stunting and reduced leaf development 59
Misshapen fruit 59

Diseases Caused by Fungi, Bacteria or Viruses (Infectious/ Biotic Agents) 60
Diseases that attack foliage 60
Diseases that attack fruit 62
Soil borne diseases/diseases that attack the root system 64
Other strawberry diseases 66
Diseases caused by viruses and phytoplasmas (virus-like pathogens) 66

Strawberry Insects 68
Insects that attack the foliage 68
Insects that attack the blossoms or fruit 70
Insects that attack the crown or roots 72
Insects that attack the whole plant 73
Other insect pests 74

Other Strawberry Pests 76
Nematode problems in strawberry production 76
Root lesion nematodes 76
Other nematodes 76
Bird damage 76

Weed Management 78
Precaution – phytotoxicity 78
Preparing the land 78
On newly-planted strawberries 78
After transplanting 79
Four to six weeks after transplanting 79
In established beds 79

Resources 80
Provincial grower association contact information 80
Provincial government resources contact information 80
Pesticide information 81
Plant health diagnostic laboratory facilities 81
Soil testing/analysis laboratories 82
Other soil test laboratories 82
Water analysis and interpretation 83
Other strawberry information 83
Other resource materials 84

Appendix 85
Feel method for estimating soil water available for crop use 85

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Abbreviations used here and for photo credits:

AAFRD – Alberta Agriculture, Food and Rural Development
SAFRR – Saskatchewan Agriculture, Food and Rural Revitalization
MAFRI – Manitoba Agriculture, Food and Rural Initiatives
OMAF – Ontario Ministry of Agriculture and Food
NYSAES-Cornell – New York State Agricultural Experiment Station, Cornell University
ARC – Alberta Research Council

Introduction

Statistics

There are approximately 523 ha (1,300 acres) of strawberries in production on the prairies. This small, developing industry has an annual gross income of 6.1 million dollars. Table 1 shows current and projected production area estimates.

Most strawberries grown on the prairies are marketed on a u-pick basis. However, in areas of market saturation, direct sales to hotels, restaurants, institutions, roadside stands and processing outlets are on the increase. Manitoba's u-pick industry is levelling off and is diversifying into other fruit crops and markets. In Saskatchewan and Alberta, the u-pick industry continues to become established and is expected to continue to grow. Based on a per capita consumption of 2.4 kg (5.3 lb.), the total prairie strawberry industry has a potential to expand to 1,926 ha (4,700 acres).

Purpose of the guide

This guide outlines the general practices and fundamentals for commercial strawberry production on the prairies. This information should not be considered a comprehensive review of all types of strawberry production systems, but solely of those systems that have been found to work well on the prairies.

Growers should adapt this information to their own farms. For example, the frequency of insecticide applications may have to be increased during an early, hot, dry spring when insect populations build up rapidly. Similarly, fungicide sprays may be required more frequently during cool, wet summers. Monitoring for pests to minimize spray applications and costs is essential to today's strawberry grower. For optimum yields and berry quality, pesticide applications must be well timed and accurate.

To be fully informed on local conditions and new developments, growers should attend the field days and seminars planned by grower associations in each province. Membership in these associations provides many benefits to growers.

Table 1. Strawberry production on the prairies

	Area in 2004		Projection for 2010	
	Hectares	**Acres**	**Hectares**	**Acres**
Alberta	142	350	243	600
Manitoba	280	700	340	850
Saskatchewan	101	250	131	325
Total prairies	523	1,300	714	1,775

The Strawberry Plant

An understanding of strawberry plant biology will help growers adapt and modify general production recommendations to suit their specific conditions. This guide will discuss June bearing (short-day) and day-neutral (photoperiod insensitive) strawberry cultivars. Short-day types are cultivars in which the initiation flower bud is triggered by reductions in day length to 14 hours or less. In day-neutral type strawberries, flower bud initiation is not affected by day length.

Taxonomy and distribution

The cultivated strawberry (*Fragaria x ananassa* Duch.) belongs to the rose family (Rosaceae) and came from a hybridization between the South American beach strawberry (*Fragaria chiloensis* (L.) Duch.) and the North American Virginia strawberry (*Fragaria virginiana* Duch.). Although the origin of the cultivated strawberry is not entirely clear, it most likely originated in the early 18th century in France (Brittany), where horticulturalists planted *Fragaria chiloensis* and *Fragaria virginiana* in close proximity to increase fruit size and quality.

In North America, strawberry production became popular in 1838 when Charles Hovey introduced the cultivar "Hovey," a hybrid between the European *Fragaria ananassa* and the North American *Fragaria virginiana*. The cultivation of this very adaptable plant has since spread to numerous countries around the globe, including the tropics, where it is well adapted at higher elevations.

General biology

The strawberry is commonly described as a herbaceous perennial, although technically, it is a true woody plant, as shown by the formation of secondary vascular tissue in roots and crowns.

Strawberry plants may be male, female or both. Cultivated varieties have perfect flowers, with both male and female parts. The pollen is sufficiently light to be carried by the wind, but insects contribute to the process and improve pollination.

The strawberry is an aggregate fruit with a large fleshy receptacle (the bulk of the fruit) that supports numerous tiny achenes, each containing one seed. In addition to seeds, strawberries produce vegetative propagules on runners, which form the basis for commercial production.

Morphology and plant development

The principal parts of the plant are the roots, crown, leaves and flowers (see Figure 1). These parts will be described here and will be referred to in sections outlining cultural practices.

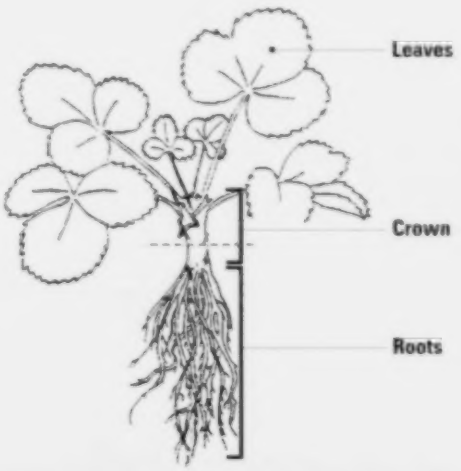


***Figure 1**. Major parts of the strawberry plant*

The root

The root system of a mature, vegetatively propagated plant typically consists of 25 to 35 adventitious main or primary roots with secondary branching occurring 2 to 5 cm (1 to 2 in.)

roots from the base of the crown (see Figure 2). Water and minerals are absorbed through fine feeder roots that are white when young. As these roots age, they become suberized and lignified and no longer function as feeder roots.

Primary roots may live for one or more years. In older plants, new primary roots emerge above the existing ones. For optimal root growth, good soil moisture is required. Under drought stress, new primary roots remain short and do not develop feeder roots. Waterlogged conditions, on the other hand, cause feeder roots to die, which opens the way for pathogens.

Strawberry roots do not penetrate deeply into the soil; in fact, the largest proportion of the root mass is usually located within 15 cm (6 in.) of the soil surface. Some roots may reach below 30 cm (12 in.). In day-neutral strawberry cultivars, the root system tends to be shallower, with most roots in the top 8 to 10 cm (3 to 4 in.).

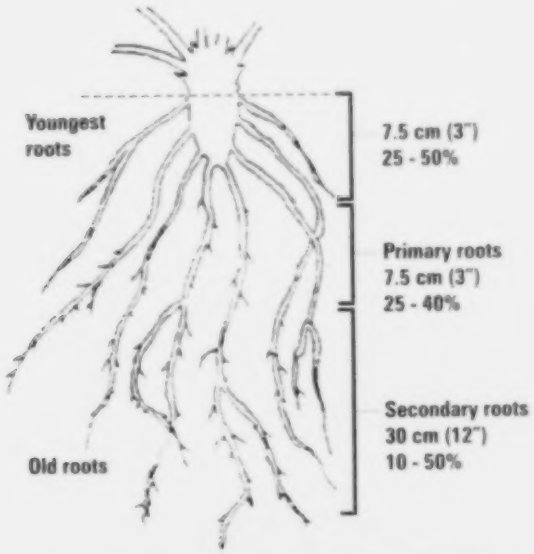


Figure 2. Strawberry root structure and distribution in soil

The crown

The crown is a short stem with spirally arranged leaves developing at the nodes. Axillary buds are located on the nodes at the base of the petioles (see Figure 3). These axillary buds may grow and form runners (stolons), side or branch crowns, or remain dormant. The crown is terminated by an apical meristem, from which the inflorescence develops (see Figure 3).

Environmental factors like day length and temperature influence the development of axillary buds. The buds of June bearing strawberries develop into runners during the summer's long 14 to 16 hour days. Once the days grow shorter in August and September, the buds no longer form runners. Instead, they form branch crowns and flower buds. The more branch crowns formed, the greater the potential for fruit production during the next year since each crown can produce one flower stalk on which fruit is borne (see Figure 3).

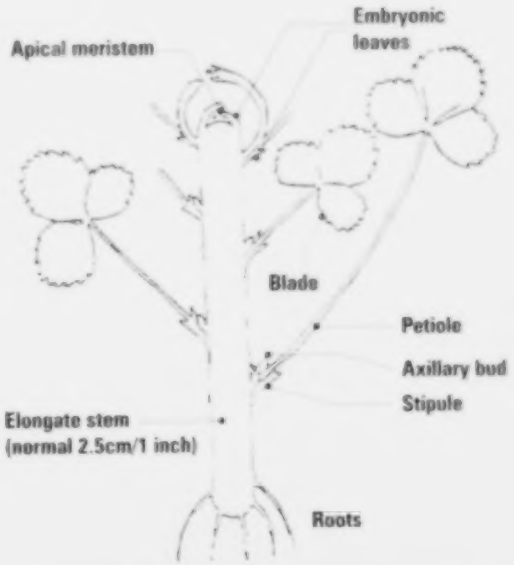


Figure 3. Strawberry crown structure – elongated

An actively growing crown will produce a new leaf every 8 to 12 days (see Figure 4). Individual leaves may live up to 3 months before they senesce, but remain attached to the crown until partially decayed or until removed by some mechanical means. Chilling at temperatures below 7°C (44.6°F) is required to promote maximal vegetative growth. Leaf number, leaf size and the number of runners increase with the duration of exposure to cold temperatures.

A cross section of the crown will reveal three types of tissue: the outer cortical and epidermal zone, the vascular tissue, and the pith. The cortical and epidermal zone protects the vascular tissue, which is responsible for the transport of plant nutrients and water. The pith serves as storage for the nutrients required during fruiting.

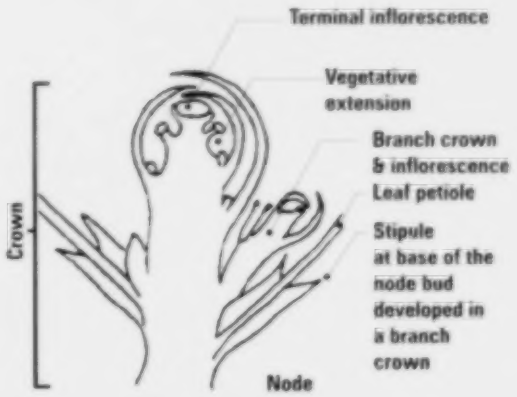


Figure 4 *Strawberry growing point structure*

Development of runners

Runners (or stolons) are modified stems with new plants forming at every second node. A typical runner consists of two long internodes, which have the effect of moving the daughter plants away from the mother plant. The first node usually remains dormant or occasionally may produce another runner, whereas the second node produces the daughter plant (see Figure 5).

Once a daughter plant has formed, further elongation of the runner will lead to the production of a second and even a third daughter plant. A well-established mother plant may produce 10 to 15 runners with up to 60 or more daughter plants. The mother plant will continue to support the daughter plants with water and carbohydrates until they are fully established.

Flower stalk (inflorescence)

The development of the flower stalk or scape proceeds from the tips of the primary and lateral (branch) crowns. The flower stalk is determinate, which means that flower production does not proceed beyond the primary flower. The inflorescence develops a central or primary flower that opens first. This primary flower is followed by smaller secondary, tertiary and quaternary flowers, which open up in sequence (see Figure 6). The large primary flower develops into the largest berry, known as the "king" berry.

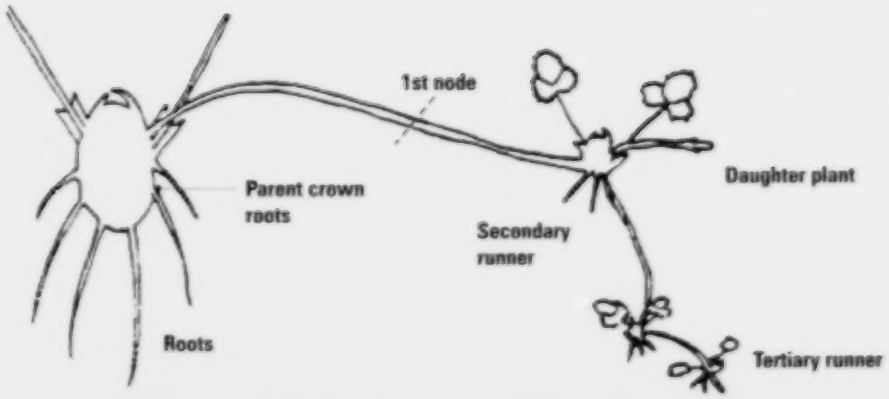


Figure 5 *Strawberry runner growth*

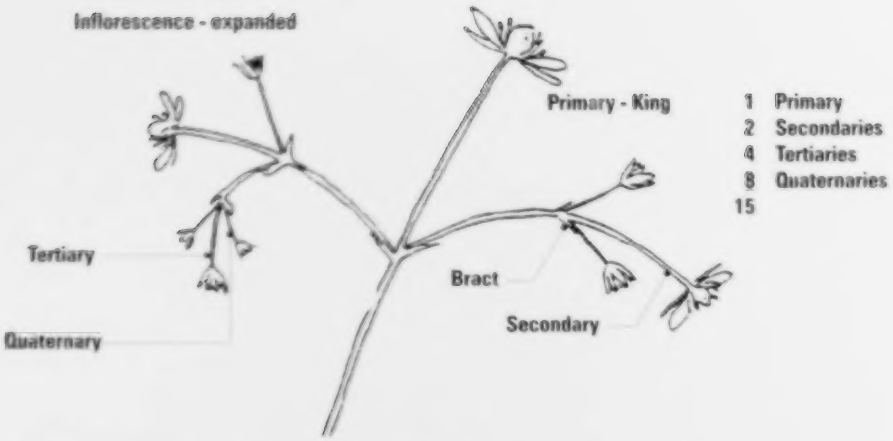


Figure 6. Strawberry inflorescence

The flower structure is illustrated in Figure 7. There are 10 sepals, 5 petals and 20 to 35 stamens (male parts) with 60 to 600 pistils (female parts). The king blossom has the largest number of pistils. The number of pistils determines flower and fruit size.

Strawberry flowers can be either self-pollinated or cross-pollinated. The pollen is sufficiently light to be transported by wind, but insects also play a major role in pollen transfer. Cool or wet weather discourages bees and results in poor or partial fertilization, which, in turn, leads to misshapen berries or nubbins. This outcome results because development of the fleshy receptacle is determined by the presence of fertilized ovules enclosed in the pistils.

It usually takes about 30 days for flowers of June bearers to develop into fruit. This period may be reduced to 18 days with good growing conditions and high temperatures. Adverse conditions like cool weather could extend development to 40 days or more.

The stamens and pistils of strawberry flowers are particularly sensitive to frost injury. Varieties adapted to colder climates may tolerate temperatures down to -3°C (26.6°F) without injury. Frost-damaged flowers will typically have blackened stamens and pistils (see Figure 32 in colour image section) and will not develop into berries.

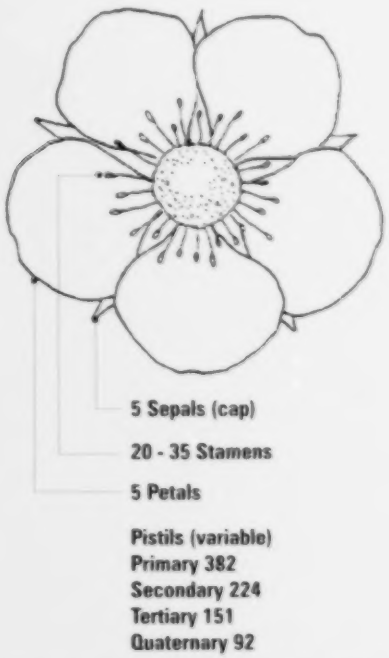


Figure 7. Strawberry flower structure

For optimal flower production and yield, moderate temperatures are required. In June bearing (short day) strawberries, day/night temperature cycles of 18/14°C (64.4/57.2°F) have been shown to substantially increase flowering when compared to day/night cycles that average above 20°C (68°F). Daytime temperatures of 25°C (77°F) or more and similar evening temperatures reduce flower initiation in day-neutral strawberries.

Preliminary Considerations

Market assessment and development are critical components of a successful strawberry operation. Ideal marketing sites are located within 50 km (30 mi.) of a city or large town, or along a tourist/resort route. A rough rule of thumb regarding population per picking area is 4,900 people to 1 ha (2,000 people to 1 acre) within a 1-hour drive. All-weather roads and adequate off-road parking space are also essential to u-pick marketing.

Strawberry growers must be innovative and have good customer relation skills. An inability to work well with people may limit success and should be considered when planning an operation. Partnerships may improve success by allowing partners with different strengths to complement each other.

Unlike traditional crops such as grains and oilseeds, strawberries are an intensely managed crop, requiring precise timing. Yields and quality achieved during the short three-week picking season hinge on timely management practices of the previous year, as well as care and maintenance before picking.

Growers entering the industry need these basic requirements:

- suitable land
- access to an adequate quantity and quality of water for irrigation
- financial resources that permit a significant level of investment plus input costs
- the ability to apply intensive management skills to the crop in a precisely timed manner
- the ability to determine market potential
- the willingness to accept risk

New growers should proceed on a small but graduated scale. Increases in the size of the production unit should be accompanied by increased knowledge gained from experience and study, including a continuing evaluation of the market potential. If you decide to become a commercial strawberry grower, you will need to consider a number of production and marketing aspects.

Site Selection

Site selection can have a significant bearing on the success of a u-pick operation. After doing market research and investigating market potential for a feasible operation, you need to consider factors relating to the proposed site such as soils, previous crops, water quality, microclimate and shelterbelts.

Soil considerations

Soil testing

Soil tests should be used to determine the suitability of a field for strawberry production and to guide the ongoing fertility management program.

The quality of the laboratory results is connected to the soil sampling procedure used to obtain the sample. For detailed soil sampling instructions, contact your local agricultural office or provincial soil-testing laboratory.

Key points to remember in soil sampling:

- Use proper augers and clean containers for sampling.
- Most soil sampling is done in the fall, due to nutrient stability; however, samples can be taken in the spring. Sample well before transplanting or renovating to provide sufficient time for the sample to be processed and for recommendations to be returned.
- Sampling depths are 0 to 15 cm (0 to 6 in.) and 15 to 60 cm (6 to 24 in.).
- Do not sample in locations where fertilizers have been incorporated recently.
- Avoid taking samples from unusual or atypical areas within the field (i.e. low boggy areas, areas with manure piles, etc.).
- Air-dry the soil sample immediately after sampling (growers often overlook this step).

Soil test reports

Providing the laboratory with field description and cropping history information allows them to maintain records for research purposes. More importantly, it helps the lab make sound fertilizer and management recommendations for the grower. Over time, individual growers can monitor the fertilizing history and nutrient levels in their fields.

The following information will help you understand and use the results of a soil test report.

Carbonate Content indicates the calcium carbonate content of the sample. High to very high calcium levels in the soil can restrict nutrient availability to the plants. The absence of calcium carbonate does not mean the fields require lime, as most prairie soils have sufficient lime. Only very acid soils require additions of lime.

pH indicates the acidity or alkalinity level of the soil. Soils with a pH in the range of 5.5 to 7.5 are usually satisfactory for strawberry production. pH is important because it influences the solubility or availability of mineral elements required for plant growth (see Figure 8). Phosphorus, for example, becomes less available to plants at levels below pH 5.3 and above pH 7.5. Nitrogen is available in the pH 5 to 8 range. Soil pH greater than 7.5 has been associated with yellowing of strawberries caused by the lack of iron uptake in the plant leaf tissue.

Alkaline soils can occur in bands or patches throughout a field. In strawberry production, this situation can cause yellowing or chlorosis of the plants, a condition that can lead to significant yield losses or complete plant dieback.

The use of green manures and acidifying fertilizers can alter the soil pH to some degree; however, the adjustment of soil pH is difficult to achieve and can be fairly expensive.

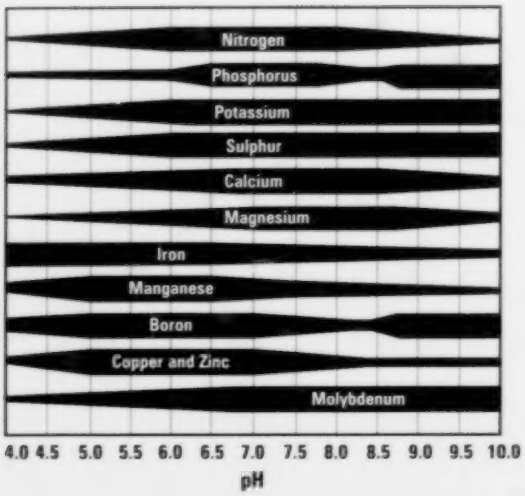


***Figure 8**. Influence of pH on nutrient availability in soil*

Conductivity measures the salinity (salt) level. The salt content (salinity) of some prairie soils is too high for successful commercial strawberry production. A conductivity reading of less than 1 mS/cm is best for strawberries. Levels greater than 1 could result in growth problems and reduced yields. For each unit increase in salinity above this threshold, yields decrease by 33 per cent.

Adding lime or gypsum will not correct a soil salinity problem.

Irrigation water with significant salt content, combined with poor soil structure, may also cause soil to develop unacceptable salinity levels.

Texture indicates the relative amounts of sand, silt and clay. The best soil for berry production is deep, well drained sandy loam, well supplied with humus (over 2% organic matter).

Loam soil is a good mixture of sand, silt and clay and is neither droughty nor difficult to till. Heavy clay soils are usually poorly drained, encourage disease development and impede precisely timed field operations. Coarse textured sandy soils are often infertile and droughty, and they require more frequent irrigation and greater attention to fertilization practices.

Plants established in low-lying muck or organic soils are more vulnerable to frost injury.

Soil Organic Matter Content measures the amount (per cent) of organic matter present in the soil. Organic matter represents a store of nutrients and has a significant effect on soil moisture and nutrient holding capacity. Soils with an organic matter content between 2 and 4 per cent are recommended for strawberries. High organic matter soils may have poor drainage, and soils with excessively low levels of organic matter may be unsuitable for strawberry production.

Nutrient Content or soil fertility levels indicate the amount of nutrients in the soil. Knowledge about these levels allows growers to make fertility management decisions, which may include the addition of fertilizers before the establishment of a field. A soil test report will contain levels of macronutrients (e.g. nitrogen, phosphorus, potassium and sulphur) and can include levels of micronutrients (e.g. magnesium, iron, etc.).

Drainage

Poorly drained sites should be avoided. The surface drainage system must permit water to move from the field quickly and completely. Water standing on the strawberry field for a day or two will injure plants, especially when they are actively growing. On sites with certain contours, such as dips, ridges and slopes, poor drainage can cause "yellowing" in strawberries. This condition can significantly reduce yields.

The use of clay or plastic drainage tile could be considered on sites where drainage is a problem. Your provincial water services branch provides an advisory service for problems of this kind.

Soil tilth

Soil tilth and nutrient availability can be improved by using green manure crops such as field peas, buckwheat, canola or rye. These crops can be rotated with the strawberry crop.

Previous crops/crop rotation

Strawberries should not be planted in soils where strawberries, raspberries, alfalfa, potatoes, tomatoes, peppers or eggplants have been grown in any of the previous four years unless the soil has been fumigated. The fungal diseases, black root rot (complex of *Rhizoctonia fragariae, Pythium species, Idriella lunata* and *Cylindrocaropon destructans*) and verticillium wilt (*Verticillium dahliae*) will attack the above crops and build up in the soil. These diseases reduce the productivity of strawberry plants. Consider fumigation if a long-term rotation that excludes the host crops is not feasible.

Sites surrounded by natural bush stands may contain native strawberry plants. These plants can harbour insects, diseases and viral pathogens that may infect cultivated strawberry stands. To maintain good sanitation, it may be necessary to kill native strawberry stands within 400 m (1,300 ft.) of commercial strawberry fields.

Water for irrigation

Irrigation is essential for both consistent, high yielding strawberry production and frost control. Since the prairies have fairly low rainfall and strawberry plants are shallow-rooted, supplementary moisture is necessary to maximize production. An average of 30 cm (12 in.) of irrigation water is required over the growing season. Water applications may also be needed for spring frost control and summer crop cooling when temperatures are excessively high.

River or pond water is often used for irrigation. Well water may be suitable, but should be tested to determine if the quality and quantity is satisfactory. Well water often has high sodium and/or iron levels.

In Manitoba, the suitability of a water source may be tested by submitting a 2 L (0.4 gal.) sample for test number 85 to EnviroTest Laboratories, Winnipeg, MB (see *Resources* section for complete address).

In Saskatchewan, water analysis is done by EnviroTest Laboratories, Agriculture Services, or the Irrigation Development Section of the Crop Development Branch, Saskatchewan Agriculture, Food and Rural Revitalization (see *Resources* section for complete addresses).

In Alberta, water analysis is done by a number of private laboratories (see *Resources* section for details).

Water quality should be satisfactory for strawberries if salinity is less than 1 mS/cm, adjusted sodium absorption ratio (SAR) is less than 30 and chlorides are less than 3 meq/L.

In the prairies, a water rights license is required before water can be taken from any source other than a pond filled completely by rain or snow that has fallen on the grower's property. Construction of ponds or dams may also require approval. Water rights licenses are issued by the Water Branch of the Water Stewardship Department in Manitoba, Alberta Environment in Alberta (provided required evaluations have been conducted), and by Saskatchewan Watershed Authority in Saskatchewan.

There are a number of assistance programs for the development of irrigation systems. For further details, contact the Manitoba Agriculture, Food and Rural Initiatives, Soils and Crops Branch, the Alberta Agriculture, Food and Rural Development, Irrigation Branch, or the Irrigation Development Section, Crop Development Branch, Saskatchewan Agriculture, Food and Rural Revitalization.

Microclimate

A microclimate is defined as the local climate near the ground that is peculiar to a small area (usually, the radius is less than a kilometre and can be as small as a centimetre). It is an area with uniform temperature, rainfall and drainage as well as good protection from the wind. These conditions are essential for successful strawberry production. If the site lacks a microclimate, you must create one.

Land that is slightly sloped provides good air and ideal water drainage. Cold air that settles in a field can result in the freezing of flower buds and fruit. Locations with good air drainage allow cold air to move away from plantings, with no restriction in

airflow. For this reason, dense wooded areas and perpendicular shelterbelt plantings should be avoided, and fields should be oriented to allow for natural air drainage. If some shelter is required, openings should be left to let cold air move away.

Water drainage is also important for strawberry plantings. Too much soil water can increase the chance of root and crown rots and can decrease plant vigour and nutrient availability. Good drainage can be a result of slope or soil texture or may be improved artificially.

Strawberry plants also benefit from adequate snowfall for winter insulation. Locations subject to lower early spring temperatures or limited snowfall are less than ideal for strawberry production.

Shelterbelts

If wind protection is lacking, shelterbelts should be planted to reduce wind velocity. Winds can dry fruit and plants during the growing season, desiccate plants during the dormant winter period, remove the winter snow cover and cause soil drifting during the plant establishment year. A properly planted and maintained shelterbelt can assist in obtaining a uniform blanket of snow to insulate plants from winter temperatures.

Permanent shelterbelts

Hedges can make good shelterbelts. Ideally, a hedge should grow quickly, take up minimal amounts of land and produce a minimal amount of shade. Competition for fertilizer and moisture is also an important consideration. When selecting shelterbelt plants, avoid the following characteristics:

- species with broad, suckering roots or volunteer seedling problems
- over-density of branches inhibiting snow infiltration
- wide spreading top
- high labour requirements for pruning
- limbs and branches susceptible to breakage from snow, ice and wind
- high seedling production

A number of ornamental plants are suitable for shelterbelts, and each has advantages and disadvantages. For specific shelterbelt recommendations, consult with your local department of agriculture or the Prairie Farm Rehabilitation Administration (PFRA).

Plant shelterbelts 122 to 183 m (400 to 600 ft.) apart and in a direction that breaks the force of prevailing winds. Do not align shelterbelts so that natural airflow patterns are blocked/disrupted. This factor is especially important on slopes, where stagnant air pockets can be created, leading to an increased risk of frost.

Weed control, especially of broadleaf types, is a must in shelterbelts. Poorly maintained shelterbelts permit weed and leaf litter accumulation that foster a build up of slug and insect populations.

Annual supplementary shelter

On the prairies, supplementary shelter should be planted approximately every 18 m (60 ft.), to enhance the effectiveness of the permanent shelter layout. Corn and sunflower plantings have been used successfully.

When establishing a sunflower hedge, seed at a rate of 9 plants/m (3 plants/ft.) to allow good wind and snow filtration. Due to a tendency for the plants to fall over in high winds, it is recommended that plants be seeded in double rows. This pattern increases the density and strength of the hedge.

Plants should be seeded as early as possible in the spring. Ensure good fertility, so maximum stalk development can take place over the summer. Flower heads should be removed before maturity to stop heads from "going to seed" or causing premature breakdown of the stalks. Fully mature heads with seeds will attract birds, an unwanted pest of the strawberry producer. If properly managed, a sunflower hedge will last several years.

Corn should also be seeded in rows at a rate of 9 plants/m (3 plants/ft.) in double rows. Corn provides excellent summer wind protection, but should not be used for protection and snow collection in winter, as the stalks will not hold up over winter.

Snow fences, plastic wind screens or lumber slabs can also be used as supplementary shelter. These materials will not compete for moisture and nutrients, and they permit the complete use of a field.

Cultivars

Cultivar choice depends on several factors:

- yield
- hardiness
- disease and insect resistance
- consumer acceptance

The performance of a cultivar at a particular site can be affected by soil type, producer management skills and climate.

Some cultivars are widely adapted in the prairie area. Red Coat, for example, is noted for its winter hardiness in the Eastern part of the prairies. However, since the introduction of new cultivars over the past decade, Red Coat is being replaced by varieties with similar hardiness, but higher fruit yield and quality.

In selecting a strawberry cultivar for a particular farm, you should consult your local variety test results and grower associations. Since cultivars may respond differently to minor climatic and soil conditions, test cultivars before wide scale adoption. Only those that do well should be selected for your farm situation. A blend of early, mid and late season cultivars can extend the harvest period and spread risk.

Two major types of strawberries are produced on the prairies: June bearing strawberries and day-neutral strawberries. While the majority of production on the prairies is with June bearing strawberries, day-neutral strawberries are also grown to a reduced degree. See the following colour image section for pictures of the varieties (Figures 9 to 15).

Day-neutral strawberries

Based on yields, hardiness and quality characteristics, the day-neutral varieties Tristar and Seascape have a proven track record on the prairies.

Tristar

- high yielding
- good late season producer
- very good hardiness
- medium vegetation
- firm fruit, very good flavour and texture

Seascape

- high yields
- bright, large, firm fruit
- good late producer
- increasing planted acres

Other varieties include the following:

Tribute

- medium-sized, moderately firm fruit
- medium, red, rounded fruit
- full flavor reached two days after turning red

Fern

- medium to high yielding
- good hardiness
- bright, attractive, large, firm fruit with light internal colour
- good texture and flavour
- not strong vegetatively
- earlier than Tristar and Seascape

Hecker

- high yielding potential
- good hardiness
- medium vegetative characteristics
- rounded fruit
- medium texture and flavour, light internal colour

June bearing strawberries

The following June bearing varieties have performed well on the prairies:

Kent

- one of the highest yielding varieties in tests conducted across the prairies
- mid season, slightly later than Red Coat, good hardiness
- medium to high vigour
- large to medium fruit with very good, firm texture and flavour
- somewhat susceptible to injury from the herbicide Sinbar
- highly susceptible to leaf spot and angular leaf spot, susceptible to leaf scorch
- tolerant to hot summer temperature, but does not stand well under wet harvest conditions
- preserves well by freezing

Glooscap

- glossy, attractive, firm, dark fruit
- potential for high yield
- very good vigour
- good flavour
- similar to Kent in maturity
- good for freezing and fresh market
- good shelf life
- susceptible to angular leaf spot, moderately resistant to leaf spot and leaf scorch

Red Coat

- winter hardy except in Alberta
- ripens in mid season
- berries are medium firm, uniform in size, medium red, maintain size well, and retain attractiveness after storage
- flavour is only fair
- light internal colour, especially if picked prematurely
- plants are strong and runner extensively
- susceptible to verticillium wilt, resistant to powdery mildew
- yields below Kent and Glooscap

Honeoye

- mid-season
- very good hardiness and vigour
- medium to large fruit that often tend to have a white tip when ripening
- attractive, large, bright fruit
- not as firm as Glooscap
- good texture and flavour (off flavour may occur on sandy soils)
- consistently productive

Bounty

- late season variety
- medium to high yield potential
- good hardiness
- medium vigour
- medium to large fruit, especially in early stages
- attractive and firm
- very good texture and flavour

Cavendish

- good yields
- large, firm fruit that hold colour and texture well in the field
- fruit are slightly pubescent and have firm skin
- somewhat location specific
- good flavour (off flavour may occur on heavier soils)
- resistant to leaf scorch, moderately resistant to leaf spot

Brunswick

- good yields
- good late season producer
- firm, shiny berries with good quality and average to good flavour
- berries smaller than Cavendish but larger than Honeoye
- resistant to Red stele

Other cultivars

The following varieties have performed less consistently throughout the prairies than those previously listed: Micmac, Sparkle, Veestar, Jewel.

New cultivars

New cultivars showing better disease resistance, fruit characteristics, specific environmental tolerances and yield increases are being released periodically. Both day-neutral strawberries and June bearing crosses are presently under test. In general, growers are cautioned to try only a small planting before adopting new cultivars for general production at their site.

Cultivars that preformed well in recent Alberta trials included Chambly and St. Pierre, which were comparable to Kent in terms of yield and fruit quality.

Color Section 1

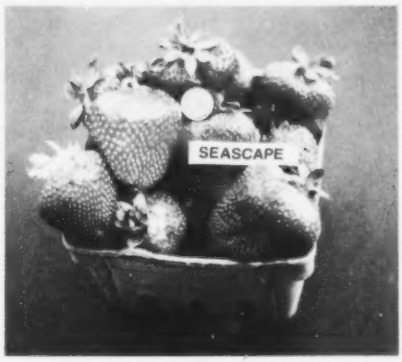


Photo Courtesy AAFRD

***Figure 9**. Seascape strawberry*

Photo Courtesy MAFRI

***Figure 10**. Fern strawberry*

Photo Courtesy MAFRI

***Figure 11A**. Kent strawberry*

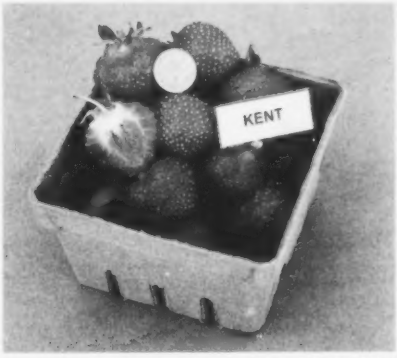


Photo Courtesy AAFRD

***Figure 11B**. Kent strawberry*

Photo Courtesy AAFRD

***Figure 12A**. Glooscap strawberry*

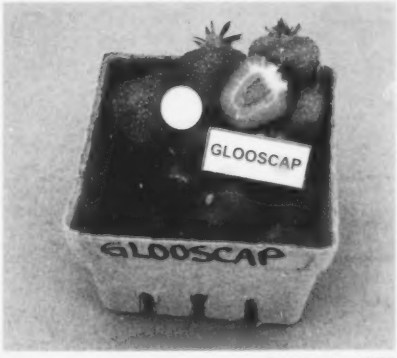


Photo Courtesy AAFRD

***Figure 12B**. Glooscap strawberry*

Photo Courtesy MAFRI

***Figure 13A**. Honeoye strawberry*

Photo Courtesy AAFRD

***Figure 13B**. Honeoye strawberry*

Photo Courtesy AAFRD

***Figure 14A**. Cavendish strawberry*

Photo Courtesy AAFRD

***Figure 14B**. Cavendish strawberry*

Photo Courtesy AAFRD

***Figure 15**. Brunswick Strawberry*

New Plantings

Soil preparation

Once the planting site has been selected, proper preparation is needed. This step generally takes two years. Land preparation is critical in terms of both soil tilth and perennial and annual weed control.

Soil preparation has three main objectives:

1. To destroy as many weeds as possible, especially perennials such as thistle and quackgrass.

Attempts to shortcut this basic production rule will result in a continuing battle to control weeds. For chemical weed control recommendations, contact the local agricultural representative or weed supervisor.

2. To add as much organic material as possible.

At least 40 t/ha (18 tons/acre) of barnyard manure should be applied to the field. Well-rotted manure should be incorporated in the spring of the year before planting to permit straw to break down. Apply poultry manure well ahead of planting at a maximum of 11 t/ha (5 tons/acre) to avoid burning strawberry roots (see Table 2).

Growing a green manure crop a year before planting is also a good practice. The residue increases organic matter and helps improve soil tilth, overall structure and water retention capacity. Suitable green manure crops are rye, seeded at 125 kg/ha (2 bu./acre) or buckwheat, seeded at 81 kg/ha (1.5 bu./acre). Apply 56 kg/ha (50 lb./acre) of actual nitrogen, so the field is as fertile as possible.

Green manure also increases beneficial soil bacteria that provide for a slow release of nitrogen and trace elements to the strawberry plants. Green manure crops should be sown as early as possible and ploughed under in later summer to allow time for the incorporated crop residue to break down in the soil.

3. To ensure organic matter is well decomposed.

Work soil in the fall to get a deep and reasonably loose planting bed. A rototiller or other suitable equipment can be used. Some growers find plants grow better if placed in soil that has not be disturbed by spring tillage. This concept may be directly related to soil moisture.

Table 2. Plant nutrient values of manure

		Kg/t of manure			lb./ton of manure		
Type of manure	**Quality**	**N**	**P_2O_5**	**K_2O**	**N**	**P_2O_5**	**K_2O**
Cow	Good*	2.5	1.5	4	5	3	8
	Poor**	1.0	0.5	3	2	1	6
Poultry	Good*	5.0	3.0	4	10	6	8
	Poor**	3.0	2.0	3	6	4	6

NOTE: *well rotted, but not leached; **excessively rotted and leached

N = nitrogen, P_2O_5 = phosphate, K_2O = potassium

Care of nursery plants before planting

Plants will keep in storage at 1 to 3.3°C (34 to 38°F) for up to two weeks. Once temperatures rise above this level, rot develops and drying occurs more quickly. Do not refrigerate plants that have initiated any growth. Temperatures of 4.4 to 10°C (40 to 50°F) can be permitted temporarily, provided the plants are checked frequently for mould development.

Take plants out of cold storage the day of planting and cover them with a tarp until they are to be planted. Plants should be watered to keep the roots from drying out during planting. A cold, cloudy day is preferred for planting over a hot, windy day.

For temporary storage, plant crates should be put in a shaded, cool location and covered with wetted burlap bags. If planting must be delayed and cold storage facilities are unavailable, keep plants as cool as possible and check for mould periodically. Plants can be safely kept for 7 to 10 days in this manner.

For longer periods, plant bundles should be separated and put in a shallow, V-shaped trench, with roots spread out and crowns covered at ground level with soil. Firm soil slightly around the roots and leave plants in this condition ready for planting. Locate plants in a well-drained area, sheltered from the sun and wind.

Avoid plants from bundles that have grey mould on the roots when they are unpacked. Discard plants with mould development on the upper root and lower crown areas.

Planting

Planting steps

Always buy certified plants when starting a new planting. Plant quality has a direct bearing on the plant's eventual performance and yield (see Figure 16).

Plant as early in the spring as soil conditions will permit. Be aware that planting into wet soil will result in poorly set plants, which will decrease survival. Certified plants cannot be expected to perform at their best with improper handling and poor planting conditions.

Photo Courtesy AAFRD

***Figure 16**. Strawberry crowns at planting*

Short rows make thorough picking easier to manage, while long rows facilitate cultivation, spraying and other field practices. Generally, a row should not be longer than 10 sprinkler head spacings or approximately 122 m (400 ft.). The use of cross aisle-ways allows for easier picker management of long rows. Align rows for efficient layout of irrigation pipes.

It is very important to apply water to the young transplant after planting. Waiting for several hours before watering can reduce plant vigour for several years after establishment.

Plant rows so they fall within the irrigation spray pattern. Avoid planting too close to shelterbelts because of shading and competition for moisture and nutrients. Depending on the shelterbelt species, the distance from the shelterbelt to the first row of strawberries may range from 15 to 30 m (50 to 100 ft.).

Planting distance

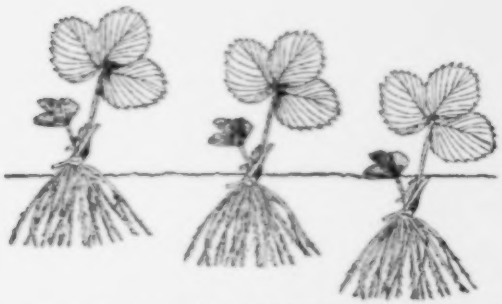
In Alberta and Saskatchewan, strawberry rows are planted 1.2 to 1.5 m (4 to 5 ft.) apart, with plants about 30 cm (12 in.) apart in the row. In Manitoba, most growers plant the strawberries 20 to 30 cm (8 to 12 in.) apart. On average, most growers

estimate an average of 27,000 to 31,000 plants per hectare (11,000 to 12,000 plants per acre). The prairie growing season is short, and closer planting in the row helps establish a full matted row in the first year.

If the width of the picking row is kept at 30 to 40 cm (12 to 15 in.), a planting distance of 0.9 to 1.1 m (3 to 3.5 ft.) between the rows can be used. For a picking row width of 60 to 76 cm (24 to 30 in.), a between-row distance of 1.2 to 1.4 m (4 to 4.5 ft.) is required (see Table 3).

Planting depth

Set each plant so the mid-point of the crown is level with the soil surface (see Figure 17). When plants are set too deeply, rot may develop, and runnering will be delayed and reduced. If plants are set too shallow, the crown and the top portion of the root can dry out, reducing the potential for rapid establishment.



Adapted from "Food Gardens for Defence," 1942. M. G. Kains. Grosset & Dunlap. New York

***Figure 17**. Proper crown placement: Left – too shallow, Right – too deep*

Most plants are machine planted (see Figure 18). Adjust the machine so the plant roots are placed in a vertical position in the soil. Roots longer than 15 cm (6 in.) may be trimmed to that length. Always have someone follow the transplanter to check planting depth and reset any plants that are not properly planted.

Photos courtesy MAFRI & AAFRD

***Figure 18**. Mechanical transplanting of strawberry crowns*

Table 3. Number of plants per hectare/acre required at various in-row and between-row spacings

Spacing in the row (m)	Between the rows (m)	Approximate number of plants/ha	Spacing in the rows (ft.)	Between the rows (ft.)	Approximate number of plants/acre
0.30	1.07	31,153	1.00	3.50	12,446
0.30	1.22	27,322	1.00	4.00	10,890
0.30	1.53	21,786	1.00	5.00	8,712
0.46	1.07	20,317	1.50	3.50	8,297
0.46	1.22	17,819	1.50	4.00	7,260

Growers have designed several machines to firm soil around newly planted strawberry crowns. Packers have been made using two wheels with rubber tires in a frame that inclines the wheels toward each other at the bottom. As this packer rolls over the planted row, it firms soil tightly around the roots. Another method of packing is by driving an all terrain balloon-tire tricycle with its middle tire over the planted row. The wide, low-pressure tire is ideal for firming soil around the new transplants without causing damage.

A small "shot" of water or water-soluble fertilizer solution at the time of transplanting is beneficial when soil moisture is low. Applying too much water will cause the roots to float up before being covered with soil, creating a "J-root" placement as opposed to a properly fanned-out placement.

After soil has settled because of watering or wind erosion, a light cultivation is recommended to replace soil around the crown. This "hilling" process works well with lighter soils. However, be careful not to bury the crown when hilling with heavier clay soil types.

Fertility management

Objectives of a fertility management program:

- promote rapid and early runnering of new plants
- promote rapid growth, development and early runner formation before the end of July
- maximize crown formation after late August of the establishment year

Fertilizer rates must be based on sound data derived from soil testing and plant tissue analysis. Estimated nutrient levels or general recommendations are not sufficient for maximum yields. Pay careful attention to timing and application methods.

Fertilizer application before or at planting

Apply and incorporate fertilizer as recommended by the soil test, paying close attention to phosphorus content. Depending on the fertilizer type used, sulphur may or may not be included in the mix. Pre-plant herbicides may also be incorporated at this time.

Fertilizers high in phosphorus, such as 10-52-17 or 10-30-10, can be added to water applied during transplanting. Dissolve the fertilizer at a rate of 0.5 kg/455 L (1 lb./100 gal.) of water, and apply this solution at 0.14 L (5 oz.) per plant. Some mechanical planters automatically apply starter solution to each plant.

When fertility is adequate, water alone may be sufficient to provide the transplants with a good start.

Fertilization after planting

After the plants are in the soil, their fertilizer needs require attention. Proper fertilization of the strawberry plants is a key element in successful production. You need to know what the major nutrients are and what affect they have on plant and fruit development.

The major nutrients include nitrogen, phosphorus, potassium, sulphur and calcium. Each deserves some discussion to demonstrate its significance. In addition, micronutrients can affect plant vigour and berry quality.

Nitrogen

Nitrogen is one of the most important elements in strawberry production. Nitrate nitrogen, the form most readily used by plants, is indicated in kg/ha (lb./acre) in soil test results.

The timing of nitrogen application has a direct bearing on yield, fruit quality and plant development. Nitrogen applications in late summer often promote flower bud formation for the next year's crop and may increase branch crown formation and benefit overall production.

High nitrogen rates are likely to increase the number of runners. This situation could be a disadvantage because too many runners can create high populations and excessive competition. Nitrogen application in late fall may delay normal dormancy and cause an increased risk of winter injury.

Generally, nitrogen is fairly mobile in the soil and can move into the plant quickly. It can be affected by a number of environmental factors, including rain or irrigation. In saturated soil conditions, nitrate nitrogen rapidly converts to a gas (denitrification) and is lost. Nitrogen deficiency of strawberry leaves can appear as yellowing or chlorosis or a reddening of the leaves (see the section on *Abiotic, Non-infectious Diseases*).

Nitrogen should be applied and incorporated before planting at a rate based on soil test results (see Table 4 for recommended rates). When new plants have established their own root system or if plants grow slowly and have small, light-green leaves, 17 to 22 kg/ha (15 to 20 lb./acre) of actual nitrogen should be side-dressed or placed directly on the row. Repeat the application one month later if no response is seen after the first application or at the early stages of runnering.

If fertilizer is applied to the surface, ensure foliage is dry, and brush all fertilizer pellets off the plants by dragging burlap or a light chain over the row behind the applicator. In late August, apply 28 to 56 kg/ha (25 to 50 lb./acre) of actual nitrogen to help fruit bud formation.

Phosphorus

The phosphorus value in a soil test report describes the ability of the soil to supply phosphorus to plants. It is measured in kg/ha (lb./acre). Phosphorus is measured only at a depth of 0 to 15 cm (0 to 6 in.).

Phosphorus moves slowly in the soil. Its availability to plants depends on soil pH as well as the actual phosphorus content of the soil. Most prairie soils tend to be alkaline, which results in low levels of available phosphates.

This nutrient is especially important for root and seed development; therefore, special attention should be given to phosphorus requirements when preparing fields for planting. Adequate supplies are needed to promote early production of daughter plants, good vegetative growth and runnering (see Table 5 for recommended rates).

Table 4. Nitrogen recommendations based on soil test results kg/ha (lb./acre)

Nitrate/nitrogen content 0 - 60 cm (0 - 24 in.)		Nitrogen availability content	Nitrogen (N) recommended	
kg/ha	lb./acre		kg/ha	lb./acre
5 - 9	(4.5 - 8)	VL	130 - 121	(116 - 108)
20 - 24	(18 - 21)	L	100 - 91	(89 - 81)
35 - 39	(31 - 35)	M	70 - 61	(62 - 54)
50 - 54	(45 - 48)	H	40 - 31	(36 - 28)
65 - 64	(59 - 57)	VH	10 - 1	(9 - 0.9)

VL = very low, L = low, M = medium, H = high, VH = very high

Potassium

Potassium readings are measured in kg/ha (lb./acre) and are a measure of the soil's ability to provide potassium to the plant. Potassium is measured only at a depth of 0 to 15 cm (0 to 6 in.).

Potassium is associated with strong leaf petioles, sturdy fruit stalks and increased winter hardiness. It is also needed for good fruit colour and sugar content.

Many prairie soils have sufficient potassium to meet plant needs. Sandy soils below 2 per cent organic matter require higher applications of potassium (see Table 6 for recommended rates). Potassium deficiencies are shown in the section on *Abiotic, Non-infectious Diseases*.

Sulphur

Sulphur is measured in kg/ha (lb./acre). The value in a soil test report indicates the amount of sulphate-sulphur in the top 60 cm (2 ft.) of soil.

Sulphur is mobile in the soil. For most prairie soils, sulphur-containing fertilizers like super phosphate and ammonium sulphate provide adequate levels for good plant growth. Higher levels have been found beneficial in lowering the pH in some alkaline soils on the prairies (see Table 7 for recommended rates).

Table 5. Phosphorus recommendations based on soil test results kg/ha (lb./acre)

Exchangeable phosphorus in soil 0 - 15 cm (0 - 6 in.)		Phosphorus availability category	Phosphorus (P) recommended	
kg/ha	lb./acre		kg/ha	lb./acre
5 - 11	(0 -10)	VL	110 - 102	(98 - 91)
12 - 19	(11 - 17)	L	101 - 96	(90 - 86)
20 - 28	(18 - 25)	M	95 - 89	(85 - 79)
29 - 49	(49 - 44)	H	88 - 81	(79 - 72)
41 - 100	(37 - 89)	VH	80 - 35	(71 - 34)

VL = very low, L = low, M = medium, H = high, VH = very high

Table 6. Potassium recommendations based on soil test results kg/ha (lb./acre)

Exchangeable potassium in soil 0 - 60 cm (0 - 24 in.)		Potassium availability content	Potassium (K) recommended	
kg/ha	lb./acre		kg/ha	lb./acre
32 - 63	(29 - 56)	VL	213 - 165	(190 - 147)
128 - 159	(114 - 142)	L	177 - 165	(158 - 147)
244 - 255	(218 - 227)	M	141 - 129	(126 - 115)
320 - 351	(285 - 313)	H	105 - 93	(94 - 83)
416 - 447	371 - 399)	VH	69 - 55	(62 - 49)

VL = very low, L = low, M = medium, H = high, VH = very high

Table 7. Sulphur recommendations based on soil test results kg/ha (lb./acre)

Soil sulphate-sulphur content 0 - 60 cm (0 - 24 in.)		Sulphur availability category	Sulphur (S) recommended	
kg/ha	lb./acre		kg/ha	lb./acre
0 - 11	(0 -10)	VL	30	(28)
11 - 22	(10 - 20)	L	30	(28)
23 - 33	(21 - 29)	M	30	(28)
34 - 44	(30 - 39)	H	0	(0)
45 - 66	(40 - 59)	VH	0	(0)

VL = very low, L = low, M = medium, H = high, VH = very high

Calcium

Calcium is an essential component of cell walls, contributing to structural strength. Plant deficiencies in calcium result in soft fruit and tip burn of leaves. Typical prairie soils tend to have adequate levels of calcium in the components of the soil; however, calcium is relatively immobile in the soil and plant. Calcium can be tied up in the soil if soil pH becomes acidic (pH <7). Infrequent or uneven watering or if other minerals are present in high levels (e.g. potassium, manganese, magnesium) can result in uneven calcium uptake and deficiency symptoms. Symptoms will typically be observed in the new growth farthest from the root system.

Micronutrients

Micronutrients (zinc, copper, manganese, boron, chlorine, iron and molybdenum) rarely affect plant growth. However, the availability of micronutrients can be affected by imbalances in soil pH or by uneven application of major nutrients like nitrogen, phosphorus, potassium and sulphur. These deficiencies may affect plant vigour and berry quality. For example, field trials have shown yield reductions of 15 per cent where iron is deficient in plants.

Nutrient problems can be overcome through the use of foliar sprays containing the required nutrients. However, nutrient levels should first be verified with plant tissue testing. Table 8 gives normal ranges for various nutrients in strawberry plants.

Plant tissue testing

Plant tissue testing can determine if soil nutrients are being taken up in adequate amounts by the strawberry plant. Even when nutrients are in adequate supply, a plant's ability to use available nutrients can be affected by several factors, including soil temperature, root development, drought, high temperatures, soil saturation with water as well as fertilizer application methods and timing.

Table 8. Plant tissue analysis for determining the mineral status of strawberries

Nutrient	Normal range	Nutrient	Normal range
Nitrogen	2.0 - 3.0%	Sulphur	0.15 - 3%
Phosphorus	0.25 - 0.4%	Zinc	20 - 250 ppm
Potassium	1.3 - 2.5%	Manganese	50 - 250 ppm
Calcium	0.8 - 1.8%	Iron	60 - 250 ppm
Magnesium	0.25 - 0.5%	Boron	25 - 50 ppm

Tissue testing results can help growers avoid long term nutrient problems. Occasionally, severe nutrient problems are encountered early in the growth of a crop. A tissue analysis may allow time for corrective measures to be taken in the same season, thereby reducing the potential loss.

Normal nutrient levels in strawberry tissue vary with the plant growth stages, such as flowering, fruiting and after fruiting. Tissue values may also be affected by the time of sampling, the age of the leaves and the cultivars sampled. However, deficiency levels are reliable indicators that nutrients must be added.

As in soil sampling, the correct procedures for tissue test sampling are important. Key points to remember:

- Take care to ensure cleanliness in sampling and handling.
- Use proper sampling equipment.
- Take the plant part at the proper growth stage.
- Take a representative sample, and immediately clean and dry it with a dry cloth or soft brush.
- Avoid non-typical plants and areas in the field.
- Do not wash the sample.
- Avoid samples that have fertilizer contamination, pesticide residues or soil particles.
- Collect samples in a clean brown paper bag, not a metal container.
- Select the youngest expanded mature leaf as a sample.
- Take 25 to 30 leaves from a reasonable number of typical plants throughout the field.
- Dry the sample at room temperature.

Send these samples to a provincial or private tissue-testing laboratory (see *Resources* section for details)

Care of the young plant

Productivity over the life of the planting, especially the yield of the first bearing year, depends on the establishment of a fully matted row in the planting year.

As soon as new plants begin blossoming (June bearing strawberries), remove the flower stalk (see Figure 19). It may be necessary to go over the field two or three times to achieve this goal. This deblossoming results in earlier and increased runnering plus a more developed root system. These early-formed runners will bear most of the fruit the following year.

Photos courtesy of "The Garden," Calgary, AB

***Figure 19**: Deblossoming of newly planted June bearing strawberries*

In high-density plantings, blossoms may be left on during the establishment year and the fruit harvested. The income received helps offset the extra cost of the plants needed for high-density plantings. However, if the planting is later than normal or plants experience any stress, fewer daughter plants will form, which results in reduced yields and vigour over the life of the planting.

Avoid herbicide applications until plants are fully established, usually a period of four to six weeks. Ensure the planting is vigorous before herbicides are used in the establishment year.

During this time, cultivation and hand weeding are necessary. Cultivation should be no more than 2.5 to 5 cm (1 to 2 in.) in depth. Cultivating in the same direction each time will tend to move runners toward the row to form the desired mat of plants. This process will disturb the runners less than cultivating in the opposite direction and will allow them to set faster.

Cultivating too close to strawberry plants will disrupt the root system. Remove any soil that has flipped up onto the plant crowns. Hand weed or hoe any weeds not killed by the cultivator.

For current chemical weed control recommendations, consult the most current crop protection product information for your province. In Manitoba, consult the Manitoba *Fruit Crop Protection Guide*. Pesticide labels are also available on the Pest Management Regulatory Agency website (see *Resources* section for details).

Follow the recommendations closely, and use only chemicals registered for use on strawberries on the prairies. Be aware of the residual effect of some herbicides recommended for weed control in strawberries. This factor is especially important on lighter soils and with certain strawberry cultivars.

Irrigation of a young planting

For rapid plant development, maintain a uniform moisture level in the soil at planting time and during the initial establishment period. Do not saturate the soil with moisture, and keep in mind the potential for rainfall. During runnering, soil moisture at a depth of 1 to 1.3 cm (13/32 to 1/2 in.) should be at least 74 per cent of field capacity to facilitate rapid daughter rooting.

Spray program in the planting year

New plantings are subject to insect and disease damage, especially if the fields are adjacent to established strawberry plantings. Control measures based on periodic monitoring should be undertaken according to current recommendations.

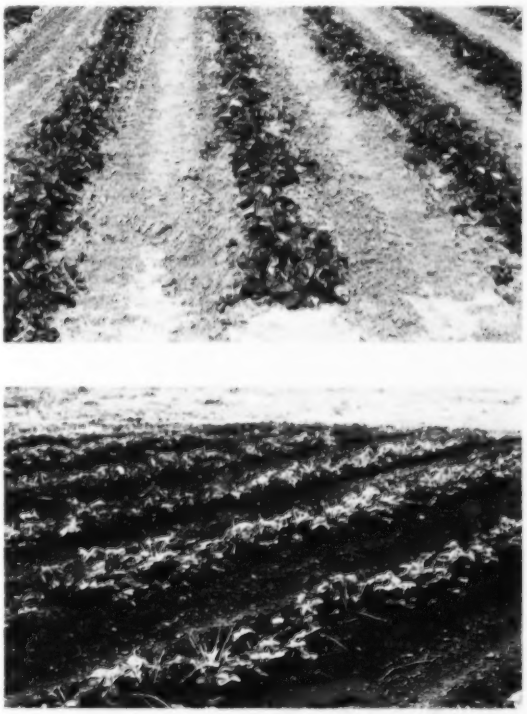
Healthy, vigorous green foliage is required throughout the growing cycle. This cycle includes the fall period when some fungal leaf spots can significantly reduce the plant leaf surface, thereby reducing the potential for storage of carbohydrates necessary for winter survival.

Management of runners

The special care given to the establishment of runners will dramatically increase yield potential in the bearing year.

Primary runners that are set early will out-yield secondary and tertiary runners. Quaternary runners usually do not root deep enough to develop significantly by the end of the season.

Once the row is full, the extra runners may be cut off (see Figure 20). Use a rolling coulter attached to the cultivator to facilitate their removal. The plantation needs frequent irrigation at runnering time. If the soil is moist, runners will develop enough root and top growth by the end of the season to survive the winter. No renovation is required in a first year planting (see the section on *Renovation*). Renovate after the first full picking season and each subsequent picking year.



Photos courtesy AAFRD & MAFRI

***Figure 20**. Young strawberry plants during runner establishment/after runner management*

Pre-winter Care

Mulching

Mulching with straw is necessary to protect the crop from low temperature injury to crowns and roots. When properly applied, mulch keeps soil temperatures more uniform, prevents plants from drying out from cold and dry winds, and helps trap snow. Mulch is usually applied in late fall after several frosts but before temperature drops to -6.7°C (20°F). Plants should be dormant. Timing varies with prairie location, but mulch is usually applied between late October and early November (see Figure 21).

Photos courtesy of "The Garden," Calgary, AB & MAFRI

Figure 21. *Fall straw mulch application*

A herbicide should be applied just before mulching to provide weed and volunteer grain control in the spring. Often, a light irrigation is required to incorporate the herbicide. For specific recommendations, consult current weed control product information for your province.

Wheat or rye straw is the best mulch material for the prairies. Use straw from grain fields that are as weed-free as possible. On a calm day, apply fresh, dry straw. This material will lie loose and fluffy and provide a good insulation layer. Rather than lying flat, straw should be sticking up to trap the snow (see Figure 22).

Photo courtesy MAFRI

Figure 22. *Snow covered straw mulch*

From 4.6 to 6.7 t/ha (2 to 3 tons/acre, 120 small bales or 10 to 12 round bales) are required. The mulch layer should be applied at 8 to 15 cm (4 to 6 inches) over the rows, 5 to 8 cm (2 to 3 in.) thick after settling.

Applying a thicker layer of straw does not provide a proportional increase in insulation. High slug populations have been associated with over-mulching. Trapped air spaces in the straw layer provide the insulation for good winter protection.

The straw spreader should apply an even cover over the entire area and should not chop the straw into shorter lengths.

A straw spreader-applicator can apply straw directly to several rows at a time, from either large round bales or small square bales (see Figure 23). The only labour required by this system is one person to drive the tractor and load the machine with the large bale. Many growers have reduced the investment in a straw spreader by building their own machine.

Mulch may blow off sites that are not properly sheltered, particularly if a combination of straw and plastic mulch is used. A slight wetting through irrigation will help keep the mulch in place (approximately 0.75 cm or 1/4 in.).

Photo courtesy of "The Garden," Calgary, AB

***Figure 23**. Straw spreader/applicator*

Straw fumigation

Many strawberries growers have difficulty finding good, clean, weed-free straw for use in their fields. As a result, a number of growers have started to use fumigated straw.

Weed seeds tend to be killed in straw when it is treated with ammonia. This process reduces weed seed introductions from straw used as mulch. Fumigated straw is also somewhat less rigid than non-fumigated straw.

Mulching with fumigated straw is an excellent way to reduce weed problems in the production of day-neutral strawberries where herbicide options are limited due to days-to-harvest restrictions.

To fumigate, straw is tarped with plastic (see Figure 24), and ammonia gas is injected at the rate of 2 per cent of the straw's dry weight. For example, a 27 kg (60 lb.) bale of wheat straw with 20 per cent moisture has a dry weight of 27 x 0.8 = 22 kg (48 lb.) Therefore, the amount of ammonia to inject into the bale would be 22 x 0.02 = 0.44 kg (1 lb.) of ammonia gas. This figure calculates to 20 kg/t (42 lb./ton) of straw.

Photo courtesy C.C. Peters

***Figure 24**. Straw bales tarped with plastic*

Picking Year

Mulch removal

Remove mulch in the spring as new growth begins and new leaves become a light yellow colour. This stage will normally occur between mid April and early May for most prairie locations.

Remove excess straw from the rows and aisles with a side delivery rake or a speciality rake. Rotary mowers are also an excellent way of removing straw (see Figure 25). The rotating blades place the straw into the aisles. Two passes over the rows will do a complete job. A beet top flailer is another machine used for straw removal. Fairly accurate adjustments can be made to the topper to allow partial removal of the straw.

Partial mulch removal delays development without harming plant growth. This practice can be used to delay bloom development and avert early frost damage to mature blooms.

Delayed mulch removal in the spring can set blooming back several days. This setback adversely affects yields and the future survival potential of plants.

Moving the straw mulch to between the rows in the spring helps keep berries clean, conserves moisture, suppresses weeds and provides a pleasant picking area.

Photo courtesy "The Garden", Calgary, AB

Photos courtesy Serviceberry Farms, Strathmore, AB

***Figure 25**. Spring straw mulch removal with rotary mower and specialty rake*

Spring fertilizer applications

Nitrogen can be applied at 17 to 22 kg/ha (15 to 22 lb./acre) to an established planting early in the spring after flower buds have started to form. If necessary, this application can be supplemented with foliar sprays, especially if the planting has shown some winter injury.

Fields that have undergone severe winter injury (see Figure 26) or that are generally lacking in vigour will respond to a band or broadcast application of ammonium nitrate at 90 kg/ha (80 lb./acre) early in the season.

Photo courtesy MAFRI

Figure 26. *Severe winter injury in strawberry field*

In most cases, nitrogen applications should be limited during the spring of the fruiting year. Excessive nitrogen in bearing plants favours the development of numerous large leaves that may hide flowers and interfere with pollination. Also, larger leaves tend to maintain wet conditions near the ground, which promotes fruit rot.

There are exceptions to this rule. For example, heavily mulched plants can have insufficient nitrogen since organisms that break down the straw use nitrogen. Under such conditions, applying up to 11.2 kg/ha (10 lb./acre) of nitrogen may increase berry size and yield, providing adequate fertilizers are used at renovation.

Pollination

Lack of proper pollination is one of the major causes of deformed berries.

Deformed berries are caused by:

- slight frost injury to blossoms
- injury from tarnished plant bugs
- lack of proper pollination

Strawberries are self-pollinated. Pollination occurs by the action of wind shaking the flower stem or through native insects and honeybees. The latter action is particularly true when bee colonies are located in the fields. Two colonies per ha (one per acre) are recommended. Insecticide sprays are toxic to bees. Pesticides should be applied late in the evening when the bees are less active and only when harmful insect populations exist.

Spray program for the picking year

Insecticides or fungicides should only be applied when insect populations and disease infections reach levels that would adversely affect profits. Eradication of all pests is not the goal of pest control. Growers should become familiar with the life cycles of both strawberry pests and beneficial insects, so as to be able to detect their presence and differentiate between pest and beneficial. Growers should inspect fields periodically.

Many pests overwinter in leaf litter in the row and start their activity even before the straw mulch removal. Plants suffering winter injury or stress appear to be more prone to injury by insects and disease; therefore, they require careful monitoring.

The tarnished plant bug, strawberry weevil or strawberry clipper can cause serious yield reductions by damaging the fruit. For more information on these pests, see the section on *Strawberry Disease and Pest Problems*.

Renovation

Renovation is the management process of regenerating a planting of June bearing strawberries after harvest to keep the planting for an additional cropping year. Renovation has the dual purpose of removing non-productive leaf mass as well as incorporating fertilizers and organic matter, aerating the soil and narrowing the rows.

The cost of renovation is much less than establishing a new planting. Some growers keep a field in production for three, four or even more years. The length of time a planting is maintained is determined by the health and productivity of the planting. Some growers will use a shorter rotation to stay ahead of disease development. If disease, insect or weed problems develop, it may be advantageous to remove the planting and start over.

Renovation is most successful if the plants are vigorous. **Renovation is not used on plantings in the establishment year of June bearing strawberries or on day-neutral strawberries.**

Strawberry plants tend to enter a stage of low activity toward the end of harvest. Renovation stimulates renewed growth and eliminates weak plants that compete for fertilizer, moisture and light.

Once the last picking is over, fields of June bearing strawberries should be renovated immediately to attain maximum regrowth in the short fall season. A week's delay may well mean a greatly reduced crop the following year. Some discretion should be used when implementing the various phases of renovation.

How to renovate

1. Immediately after the last picking (this time may vary from year to year), apply at least 56 kg/ha (50 lb./acre) of each macronutrient (nitrogen, phosphorus and potassium) directly over the rows. Nitrogen should be applied as calcium nitrate, as the nitrogen is immediately available. Some growers use fertilizers containing sulphur so that the equivalent of 56 kg/ha (50 lb./acre) is used at renovation. These higher rates also provide a slight acidifying affect to the soil.
2. Mowing encourages the development of a younger, more efficient leaf canopy. This rejuvenated canopy is more effective for "recharging" the plant energy systems of fruit formation and the overwintering food reserve build-up. Mowing also offers disease and insect control benefits, especially if the old leaves are removed from the row.

   Mow the tops of the plants to remove old leaves without cutting the new expanding growth. This level usually occurs at a height of 2.5 to 5 cm (1 to 2 in.) above the crowns (see Figure 27 in the following colour image section).

   In Alberta, mowing should be done no later than August 5 each year. In some years, harvest may not be finished before August 5, and some adjustment should be made to the mowing height. When mowing between August 5 and August 15, only the top 7.5 cm (3 in.) should be removed. No mowing should take place after August 15.

   Some growers have observed negative effects from mowing. These adverse effects can be caused by an unusually long harvest period, which leaves less time for the development of a new, full-foliage canopy or by mowing too close to the crowns, especially during abnormally hot weather. Use caution when mowing, to ensure that plants are not adversely affected.

3. Use a coulter on either side of the row, followed by raking, to move unrooted and weakly rooted plants into the aisle. This practice prevents plants from encroaching on the aisle-way. Spacing of plants with mature crowns should be 15 to 23 cm (6 to 9 in.) apart in the matted row (see Figure 28 in the following colour image section).

4. Applying recommended herbicides at renovation as an overall or banded spray can slow down the regeneration of the strawberry plant. Some hand weeding or herbicide spot treatment may be preferred to minimize plant stress.

5. Irrigate thoroughly and repeat as necessary to maintain sufficient moisture for vigorous growth.

6. An additional 17 to 22 kg/ha (15 to 20 lb./acre) of nitrogen can be applied in mid August, the time of flower bud initiation. The nitrogen source should be calcium nitrate, to ensure that the nitrogen is immediately available.

   Higher levels of nitrogen may be required on lighter soils that have been exposed to nutrient leaching by excessive rainfall or supplemental irrigation. Applying nitrogen too late in the growing season may delay the plant hardening process, which could result in winter injury.

7. Mulch for winter protection in late October to early November.

Day-neutral Strawberry Production System

The majority of commercial strawberry production on the prairies uses a June bearing strawberry production system; however, many growers are establishing day-neutral strawberries as a way to expand the picking seasons and increase revenue. While many aspects of day-neutral strawberry production are similar to those of June bearing strawberry production, a number of notable differences offer a challenge to growers.

Plant structure

Roots

Day-neutral strawberry plants have a shallower root system than June bearing strawberries, with most roots (90%) in the top 12.5 to 15 cm (5 to 6 in.). Day-neutral strawberries may have smaller root zones caused by winter injury. This point is important, as it relates to moisture and nutrient management.

Flowers

Day-neutral strawberries are insensitive to photoperiod or day length, which allows them to runner, set flower buds and produce fruit simultaneously. Runner plants will also fruit. Daytime temperatures of 25°C (77°F) or more and similar evening temperatures reduce flower initiation in day-neutral strawberries. Measures may be taken to cool the crop in these situations.

Day-neutral strawberry production cycle

Planting

As day-neutral strawberries will produce a crop in the planting year, it is important to plant them as early as possible. Day-neutral strawberries are often planted mid April to early May. A pre-plant herbicide is generally recommended before plant setting. Planting is done the same as with June bearing strawberries; however, two different plant layouts may be used.

One system involves a staggered double-row system. Plants are spaced 30 cm (12 in.) apart in a staggered double row with 1.5 m (5 ft.) between each set of double rows. This layout provides a population of 42,000 plants/ha (17,000 plants/acre). Plants are managed to prevent runner development, with a focus on fruit production in the first year. This type of system is typically only carried out when plants are being grown for only one season.

Day-neutral strawberries may also be planted in a single row system like June bearing strawberries. Plants are placed 20 cm (8 in.) apart with 1.2 m (4 ft.) between each row resulting in a population of 40,800 plants/ha (16,520 plants/acre). In this system, runners are not removed, plants are cropped, and plants are overwintered and cropped for a second season.

Cropping season management

Fertility

Fertility management in day-neutral strawberries is critical, as plants must become established quickly, and a deficiency in some nutrient can significantly affect fruit yields and quality. Due to the continuous production of leaves, flower buds, stalks, flowers and eventually runners, a continuous supply of nitrogen is required.

It is generally recommended to apply 11 to 22 kg/ha (10 to 20 lb/acre) of nitrogen in the early spring and a further 11 to 22 kg/ha (10 to 20 lb/acre) monthly in June, July and August. The monthly applications can be split to weekly or bi-monthly applications.

Derunnering/deblossoming

With day-neutral strawberries, the focus is on maximizing fruit production both in the year of planting and in the second season.

Removing the runners (derunnering) will channel more resources to the flowers and fruit, increasing first year yields. Derunnering is typically only done for crops that are being grown for a single season. Plant response will vary by cultivar.

Deblossoming (year of planting only) is carried out for some varieties (e.g. Tristar), with the purpose of allowing plants to establish before channelling resources into fruiting. As with derunnering, the response to deblossoming varies by cultivar. Deblossoming may be performed for up to six weeks.

Irrigation

Due to their relatively shallow root system, day-neutral strawberries may require frequent light irrigations. Careful monitoring of soil moisture levels is very important.

Besides supplying moisture for plant growth, an irrigation system can be used for other purposes. The production of flower buds in day-neutral strawberries slows down or ceases when temperatures get extremely warm. Therefore, some crop cooling should be implemented to ensure a crop. Light irrigation will cool crops and may lead to better yields. Irrigating for 15-minute intervals with fine-nozzled sprinklers has been found to be effective (see Figure 29).

Photo courtesy AAFRD

***Figure 29**. Micro-sprinklers for crop cooling*

Irrigation for air conditioning or crop cooling should be applied around noon on hot, dry days when temperatures reach 30°C (86°F) and relative humidity is below 30 per cent. This procedure lowers the leaf temperature, raises the relative humidity of the air and reduces the transpiration rate and water stress on the plant.

Plants require small amounts of water spread over several applications. Generally, rates of 2 mm/ha (1/10 in./acre) of water for 2 or 3 hours are sufficient. Where nozzle size does not permit a low application rate per hour, higher application rates per hour can be used if the time of application is kept short and repeated periodically throughout the hot portion of the day.

The final enlargement of the fruit can occur only when there is a minimum of water stress on the plant because moisture is needed to fill the fruit cells. Under hot, dry conditions, water may move out of the fruit into the leaves, resulting in smaller sized, lower quality fruit. This condition is called sunscald. The frequency of irrigation during the harvest season can affect berry size, appearance and sweetness.

Another application of irrigation systems is the protection of the crop from frosts. Day-neutral strawberries can be grown as an annual with little regard for spring frost damage to the flowers. However, extending the harvest period beyond the natural first fall frosts by using irrigation for frost protection can be economical.

For a detailed description of the frost control principle and the keys to successful frost control, see the section on *Special Applications of Solid Set Irrigation*.

Application of straw mulch

It is generally recommended to apply 2 to 5 cm (1 to 2 in.) of clean wheat straw 6 to 8 weeks after planting. The straw keeps the berries clean, reduces the incidence of disease, reduces soil temperature and conserves soil moisture. Fruit size in day-neutral strawberries can be directly related to soil temperature. Reducing soil temperature can also be accomplished by shading or water-cooling.

Mulching with fumigated straw is an excellent way to reduce weed problems in production of day-neutral strawberries where herbicide options are limited due to days-to-harvest restrictions. For details, see *Straw Fumigation* in the section on *Pre-winter Care*.

Post-harvest considerations

Renovation is not used on day-neutral strawberry plantings. When day-neutral strawberries are produced as a single season crop, no consideration needs to be given to overwintering. However, more producers are carrying their day-neutral strawberries for two seasons.

The overwintering process in day-neutral strawberries is similar to that of June bearing strawberries. After 3 or 4 hard frosts, herbicides are applied, incorporated with irrigation and then 10 to 15 cm (4 to 6 in.) of clean wheat straw is applied over the plants. Waiting until after the frost ensures that the plants are dormant. As with June bearing strawberries, mulch can be welded on with a light irrigation (6.25 mm or 1/4 in.). Straw should be removed when new growth is observed.

Other considerations

The diseases, insect pests and other problems observed in June bearing strawberries are also observed in day-neutral strawberries. Due to the continuous growth, flowering and fruiting of day-neutral strawberries, some problems may be observed over a longer period. Day-neutral strawberries are sensitive to 2,4-D damage over the whole season and are more sensitive than June bearers to tarnished plant bug damage.

Irrigation

Irrigation can be used for several purposes:

- to supply water to the crop
- for crop protection
- to reduce heat stress (cooling)

A properly watered crop will be less stressed and better able to survive other environmental pressures than a poorly watered one and will be less susceptible to insect damage and diseases.

Irrigation helps maximize strawberry yields in several ways. Regular watering produces large plants with large leaf surfaces, which, in turn, produce more flowers and later, more fruit. The practice also helps establish new plantings and runner rooting.

Sprinkler and drip irrigation can protect the crop from drought stress – especially during flower bud initiation in the fall. Sprinkler irrigation can protect the crop from frost damage and extreme heat. Water applications can also reduce damage to young plants and fruit caused by wind-borne soil particles. Applying water just after straw cover helps anchor the mulch to withstand fall winds. As discussed in the previous section, irrigation can also be used to incorporate fertilizers.

An irrigation system designed to supply water to the crop will not provide adequate frost protection, but may provide adequate cooling using shorter run times. A system designed to apply water applies approximately three to five times more water per minute than a system designed for frost protection.

Strawberry-water interrelations

Strawberries require regular watering because of their shallow root systems.

June bearing strawberries have 90 per cent of their roots in the top 20 cm (8 in.) of soil, while day-neutral strawberries have 90 per cent in the top 12.5 to 15 cm (5 to 6 in.). Both types of strawberries may have smaller root zones caused by winter injury or age of the plants (older plants have shallower root systems).

The crop's susceptibility to drought makes irrigation particularly effective for strawberry production. A 2.5-fold increase in yield has been recorded with some cultivars grown under irrigation versus non-irrigated strawberries.

It is most efficient to irrigate early in the day, when evaporation losses can be kept to a minimum. Straw mulch also greatly reduces evaporation from the soil.

Strawberry irrigation requirements and timing

Day-neutral strawberries may require higher rates of irrigation or more careful monitoring of soil moisture levels than June bearers because of their shallow root systems. Drip irrigation on light soils with black polyethylene mulch may require application rates as high as 5 L/m^2 (0.1 gal./sq. ft.) per day. Research has shown that without mulch, a rate of 30 L/m^2 (0.75 gal./sq. ft.) per day should be sufficient.

Key times for irrigation:

- establishment
- initiation of berry set
- maximum final enlargement of the fruit
- before signs of wilting occur (otherwise berry size is greatly reduced)
- after renovation of June bearing strawberries, when fruit buds are forming
- fall, just before covering, to reduce risk of winter injury

For rapid plant development, maintain a uniform moisture level in the soil at planting time and during the initial establishment period. Do not saturate the soil with moisture, and keep in mind the potential for rainfall. During runnering, soil moisture at a depth of 1 to 1.3 cm (13/32 to 1/2 in.) should be at least 74 per cent of field capacity to facilitate rapid daughter rooting.

Avoid irrigating just before picking. Based on a 2-day picking interval, irrigate immediately after picking with 6 to 8 mm (1/4 to 1/3 in.) of water.

The risk of winter damage may increase when plants are under stress from lack of moisture. Plants should have access to a good level of moisture right up until mulching. The cold hardening process is mainly controlled by the shorter days and cooler temperatures and is not hastened by withholding moisture.

Normal autumn rainfall amounts should be taken into account to avoid over-saturation of soils before covering with mulch.

Take care to avoid excessive irrigation, which can leach herbicides and nutrients out of the rooting zone. Too much moisture can diminish yields, reduce fruit quality and increase fruit rot development. For more detail on irrigation scheduling, consult the worksheet on determining soil moisture content in the *Appendix*.

Determining soil moisture levels

Soil moisture levels can be estimated using a hand-feel method. The hand-feel method incorporates two elements:

- visual observation and hands-on feel of the soil sample
- knowledge of the soil moisture holding capacity of the various soil textures

Soil moisture determination by hand-feel requires a soil-sampling corer. A detailed description of the hand-feel method of moisture determination is included in the *Appendix*.

Soil moisture levels can also be determined using soil moisture testing probes, such as a tensiometer or gypsum block. Soil moisture sensors can provide useful information, but require both calibration for your soil type as well as regular service and maintenance.

Problems with sensors occur when the soil dries below recommended soil moisture levels, causing a separation between the soil and the sensor. The two may not rejoin even when the soil moisture increases to recommended levels. Soil moisture sensors vary in efficacy and cost. Contact an irrigation supply company for details.

Selecting an irrigation system

Strawberry growers can choose from several irrigation systems and accessories. Factors to consider are water source (quality), site, purpose (supply water or frost protection), investment cost, labour requirements and suitability of the system for the crop.

Drip, pivot and large gun systems will apply water, but are not suitable for frost control. Well-designed systems have the proper size of sprinklers, pipelines, pumps and filters, are well laid out and are able to meet the needs of the crop. Consult an irrigation specialist or your local irrigation equipment dealer for details on systems and layouts.

A balance should be maintained between pipe costs and power costs. The larger the diameter of the pipe, the higher the investment cost. While smaller pipes are less expensive to purchase, a larger pump using more energy is required to pump the water due to higher pump pressure caused by increased water friction in smaller pipes.

Planning an irrigation system

A basic plan should contain the following:

- a map showing the field boundaries and water source location
- elevation difference from the water source to the high point of the field
- power source – location of natural gas and electrical power lines
- highest and lowest points in proposed irrigated area
- texture and depth of soils in the profile
- rate water enters the soil
- water-holding capacity of the soil
- amount of water required for irrigation
- amount of water available for irrigation
- labour requirements – operation, maintenance and moving of system

New irrigation technology becomes available regularly. Contact an irrigation equipment supplier for information.

A solid set irrigation system for strawberries

A solid set irrigation system is designed to apply water uniformly over the entire crop at one time. A solid set system can be set up in zones to reduce the pipe and pump sizes. This type of system is expensive, but can be operated without labour during the irrigation season. A solid system can be used for frost control, crop cooling and can be adapted to irregularly shaped fields with topographical variation. Figure 30 shows a sample layout.

Solid set irrigation system components

A solid set system basically consists of the following components:

- pump
- power unit
- filter
- valves (if more than one zone)
- main line
- lateral lines
- risers
- sprinkler heads
- monitoring equipment (flow meter and pressure gauges)

Pump – A very reliable pumping system is essential, especially when water is needed to control frost.

Power unit – It is questionable whether power take-off (PTO) pumps can provide the trouble-free reliability needed for frost control, although PTO pumps and several hand-move laterals may provide an inexpensive irrigation system for the establishment year. With your insurance agent, discuss insurance coverage about liability when a tractor is running without an operator. Other options are electricity, natural gas, diesel and propane. Energy costs and the cost of installing delivery lines and the importance of convenience should be considered when choosing a power unit.

Filter – Provide proper filtration to prevent plugging sprinklers with debris from the water source.

Valves – Manual or solenoid valves will be needed if the field is irrigated in zones.

Main line – Aluminium pipe is used for an aboveground main line, while PVC pipe is used for a buried main line. The diameter of the line can range from 15 to 30 cm (6 to 12 in.).

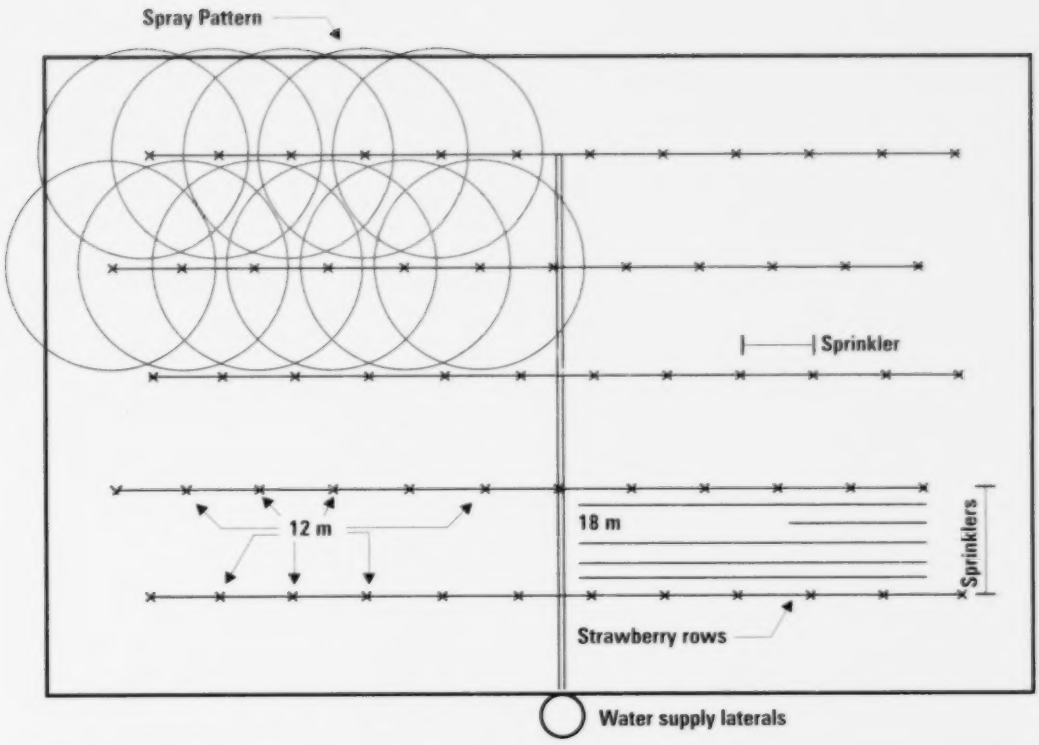


Figure 30. A solid set irrigation system

Laterals – Aluminium pipe, typically ranging from 5 to 10 cm (2 to 4 in.) in diameter, is used. Coupling types used to connect the pipe vary between companies and are generally not interchangeable. Spring couplers are not ideal if the system is moved regularly. Rubber gaskets inside the coupler seal the line against leakage while the system is operating. Self-draining couplers prevent rupture due to freezing, but are not suitable for fertilizer application.

Laterals are normally spaced 18 m (60 ft.) apart with sprinklers placed every 12 m (40 ft.) along the lateral. This pattern is commonly referred to as a 12 x 18 m (40 x 60 ft.) pattern (see Figure 30). Depending on the sprinkler selection, a 12 x 18 m pattern should give a reasonably uniform water application when wind is less than 16 km/h (10 mph). At windy sites, a 9 x 12 m (30 x 40 ft.) spacing will provide more uniform water application.

Sprinkler heads – The rotary sprinkler operates on the principle of an impact arm, which is deflected by the jet of water from the nozzle. A spring under tension returns the arm to the original position causing an impact of the arm against the sprinkler body, which results in rotation of the head.

Ideally, the sprinkler should have one nozzle open and the other tip plugged. When both nozzles are open, excessive amounts of water may be applied, and the smaller nozzle opening may plug with debris.

Sprinkler heads should not be placed opposite each other on the laterals that run side by side. Rather they should be offset, forming a triangular pattern. This pattern does not appear to be distorted as easily by wind.

Be sure sprinkler heads at the ends of laterals provide adequate coverage to the field perimeter. Locate the last sprinkler at the edge of the field to ensure the edges of the field receive the same amount of water as the centre of the field. A buffer the width of the sprinkler radius will be required.

Sprinklers used to irrigate strawberries should be designed to match the ability of the applied water to infiltrate into the soil. The application rate should not exceed 8.5 mm/hr. (1/3 in./hr.). Consider using 5 mm (13/64 in.) nozzles to apply water if the sprinkler spacing is 12 m x 12 m (40 ft. x 40 ft.).

The size of the nozzles will depend on the spacing of the sprinklers, the soil type and how long the sprinklers are operated to apply the required water. Using smaller nozzles and irrigating for a longer period may reduce the size of the pump and the pipe used to supply the water to the sprinklers. If you live in windy area, smaller sprinklers may not be effective on windy days.

A 5 cm (2 in.) diameter lateral can support up to 16 sprinklers. As a general rule, the difference in operating pressure between sprinklers should not exceed 20 per cent of the operating pressure. For an application of 3 mm/hr. (1/8 in./hr.) using a 12 x 18 m (40 x 60 ft.) sprinkler pattern, the water flow per sprinkler should be approximately 11 L/min. (3 gal./min.). A 12 x 18 m (40 x 60 ft.) sprinkler pattern would require 46 sprinklers per ha (18 per acre).

A 12 x 12 m (40 x 40 ft.) sprinkler pattern with single 4.7 mm (3/16 in.) nozzles will deliver 25.7 lpm (5.7 gpm) at 315 kPa (45 psi) and apply 10 mm/hr. (13/32 in./hr.). The first and last lateral should be placed at the edges of the field to ensure application uniformity.

If a system is operated below 0°C (32°F) degrees, ice can build up on the sprinkler heads and prevent the heads from rotating. Plastic heads can be more prone to ice build-up than metal heads.

An application of 2.5 to 3 mm/hr. (1/10 to 1/8 in./hr.) of water is required to control frost damage to plants.

Risers – The sprinklers are connected to a riser pipe that attaches to the lateral pipe couplers. Risers range in length from 15 to 60 cm (6 to 24 in.). The ideal height is 30 cm (12 in.). Higher risers interfere with field sprayer booms and other field equipment.

For an application of 3 mm/hr. (1/8 in./hr.), the minimum pump capacity required is 500 L/min./ha (44 gal./min./acre). Select a pump that provides the required flow at a pressure sufficient to efficiently operate the sprinkler where the pressure drop in the system is greatest. This calculation must take into consideration the line losses and head requirements.

Economic irrigation considerations

A solid set irrigation system costs about $6,200/ha ($2,500/acre). No return on investment can be expected in the establishment year unless the planting is a high density June bearing or day-neutral strawberry type. In these cases, cash flows are generated in the planting year. The normally high capital costs of a solid set system can be delayed until the spring of the picking year.

Less costly alternative systems like the big gun or hand moved lateral and drip systems could be used in year one.

The cost of operation is also a factor to consider when planning the system. For example, internal combustion engines require monitoring for refilling. Electricity as a power source is less costly to operate, but may be expensive to install at sites that cannot be readily be accessed by three-phase power.

Special applications of solid set irrigation

Radiation frost and freezing injury

Day-neutral strawberries can be grown as an annual with little regard for spring frost damage to the flowers. However, extending the harvest period beyond the natural first fall frosts by using irrigation for frost protection can be economical.

Radiation frost occurs on clear, cool, calm and relatively dry nights in the spring when the air temperature near the ground drops below the freezing point. Plant tissues freeze as heat is lost from the leaves, flowers and fruit (see Figure 31 in the following colour image section).

A second weather phenomenon, differing from frost, is a freeze. This event occurs when cool air masses move into the area, taking heat away from the plant by convection.

Frost damages the center of the flower (see Figure 32 in the following colour image section). The center turns black while the petals and leaves appear uninjured. The blackening occurs within a few hours to one day after the frost. Frost can also damage the developing fruit, deforming the berries.

Frost injury rarely causes complete crop loss because the strawberry plant produces flowers over a two to three week period. The first flowers to open are the largest and face the greatest risk of frost injury. Closed buds are also sensitive to frost damage. Frost losses can range from 20 to 80 per cent depending on the temperature and the duration of the frost, the cultivar, vigour, stage of development and the weather preceding the frost.

Ground level temperatures can be two to three degrees cooler than temperatures reported by Environment Canada, which are taken at shoulder level. Therefore, thermometers or electronic temperature alarms should be located in low spots where frost would usually occur first.

Mild frost damage can be controlled by management practices other than solid set irrigation. These practices include not tilling the soil during the frost risk period in early spring. Untilled soil acts as a heat sink during the day, and this heat is released during the night to protect the plants. Irrigation before a frost will provide an increased heat release from the soil by conductivity.

The use of polyethylene covers will reduce damage to flowers caused by light frosts and cold winds. Wind machines can only be used successfully under temperature inversion conditions, when a warm air layer lies over a cold air layer on the ground. A radiation frost will more often be the cause of damage to strawberry flowers on the prairies.

Frost control principle and frost injury levels

As water freezes, heat is released, keeping the plant parts above the freezing point. This frost control method is effective down to about -6.6°C (20°F). The key to utilizing this principle successfully is to leave the irrigation system operating until after sunrise to ensure that the ice will melt (see Figure 33).

A temperature of -1°C (30°F) at the plant level may cause slight injury to open flowers. Medium injury to open flowers can be expected at -2°C (28°F). Temperatures below -3°C (26°F) at the plant level will cause severe injury to buds and developing berries.

Key tools for frost control include an automatic thermal alarm, several probe sensors or thermistors and several accurate thermometers. The thermistors are placed in the flower buds of two random plants, preferably with one plant located in a low area of the field and the other beyond the frost protection system. The thermometers should be placed at the thermistor locations as a double check. A comparison of the readings at the two sites will help determine when to stop the irrigation system. These are the key steps for frost control:

- Start the sprinklers just before the air temperature at ground level reaches 0°C (32°F).
- Apply 2.5 to 3 mm/hr. (1/10 to 1/8 in./hr.). At this rate, 25,000 to 30,000 L/ha (2,200 to 2,640 gal./acre) of water is applied.
- Do not stop when ice begins to form on the plants.
- Operating time needed to control frost varies from 3 to 15 hours, but usually takes 8 to 10 hours. A slight breeze or cloud cover during the night may temporarily raise the temperature about the freezing point, but the temperature can drop below freezing just as quickly if conditions change.

- Ice may form anywhere from 1.6 to 12 mm thick (1/16 to 1/2 in.) depending on the intensity and duration of the frost (see Figure 34). This formation does not seem to injure low growing strawberry plants.
- Leave sprinklers on until the temperature increases enough to start melting the ice that has formed.

Frost control using less water

Growers with limited water supplies or poorly drained soils can achieve frost control by applying water at intervals starting at air temperatures slightly below 0°C (32°F). This delay in starting up the irrigation can reduce the water used for frost control providing careful temperature readings are taken.

This method is based on the theory that cell salts allow lower temperatures to occur within the cell without causing freezing damage. Since bud temperatures are 1 to 2 degrees warmer than freezing air temperatures, irrigation can be initiated later. This approach can reduce the time the irrigation system is in operation for frost control.

Water requirements for frost control can be reduced up to 50 per cent in several ways:

- monitoring the internal bud temperatures using a thermistor placed in the bud
- delaying the starting time of irrigation until the internal bud temperature is close to critical temperatures (-2.2°C or 28°F) rather than using the air temperature (0°C or 32°F)
- applying irrigation at varying intervals, based on the length of time it takes for water film to freeze in the buds
- stopping irrigation at sunrise

Environmental conditions like high winds during a frost can hinder the effectiveness of frost control practices. Study has shown that the key is to maintain a film of water on the bud at all times, and no plant injury will result.

Crop cooling

Light irrigation will cool crops and may lead to better yields. The final enlargement of the fruit can occur only when there is a minimum of water stress on the plant because moisture is needed to fill the fruit cells.

Under hot, dry conditions, water may move out of the fruit into the leaves, resulting in smaller size and lower quality fruit. This condition is called sunscald. The frequency of irrigation during the harvest season can affect berry size, appearance and sweetness.

Irrigation for air conditioning or crop cooling should be applied around noon on hot, dry days when temperatures reach 30°C (86°F) and relative humidity is below 30 per cent.

This procedure lowers the leaf temperature, raises the relative humidity of the air and reduces the transpiration rate and water stress on the plant. Plants require small amounts of water spread over several applications.

Generally, rates of 2.5 mm/ha (1/10 in./acre) of water for 2 or 3 hours are sufficient. Where nozzle size does not permit a low application rate per hour, higher application rates per hour can be used if the time of application is kept short, and the applications are repeated periodically throughout the hot portion of the day.

Drip irrigation

A drip system has initial investment costs of approximately $6,000/ha or $2,400/acre. Costs for establishing a system may vary. The cost of establishing the first hectare (acre) is the most expensive, due to the need for water source development as well as pipe, pump and filter costs. Economy of scale has a significant impact on the installation costs of subsequently added irrigation systems.

Most strawberry growers use solid set irrigation because of the frost control and air conditioning potential of this system. However, drip irrigation can be used successfully when growing late flowering cultivars, when water supplies are limited or when flow rates are low.

Four advantages of drip irrigation:

- high efficiency of water use
- water patterns unaffected by winds
- ease of fertilizer injection
- low initial capital cost

Disadvantages of drip irrigation:

- risk of damage caused by field equipment and rodents
- higher depreciation rate compared to a solid set system

Components of the drip irrigation system:

- pump
- filter
- main line
- sub-line
- laterals
- emitters

Plastic is usually the main material with a linear tape system. The tapes have hole spacings 30 cm (12 in.) apart. The most critical part of an efficient drip irrigation system is the filter because organic material and precipitates can plug the emitters.

More information on drip irrigation system design can be obtained by consulting the British Columbia *Trickle Irrigation Manual* (see *Resources* section for details) or by contacting to a drip irrigation equipment supplier.

Equipment for Strawberry Production

For the strawberry enterprise, equipment should be selected carefully. Consult other growers for advice on performance and general characteristics suited to the needs of the specific operation. Factors to consider include equipment flexibility, type of production and long term enterprise goals.

Tractors

Select a tractor, perhaps a small four-wheel drive unit, that is capable of powering a rototiller. A selected tractor should be capable of performing a range of farm operations, including soil preparation, spraying, and straw mulch applications. Tractor size will influence row spacing. Too large a unit will contribute to soil compaction and will be inefficient to manoeuvre.

Other equipment required

For each type of equipment, a number of models are available that can be used by growers. Choose a model that fits your particular operation.

- mechanical transplanter (see Figure 35)
  - models will vary in planting speed, suitability for different soil types, manpower requirements, etc.
- sprayer capable of delivering 1,123 L/ha (100 gal./acre) and at least 1,379 kPa (200 psi) pressure
- rototiller
- fertilizer spreader
- straw spreader/applicator (see Figure 36)
- mechanical tillage equipment (wide range of models and types available) (see Figure 37)
- irrigation equipment
- irrigation pipe trailer
- frost alarm system
- soil sub-soiler (optional)

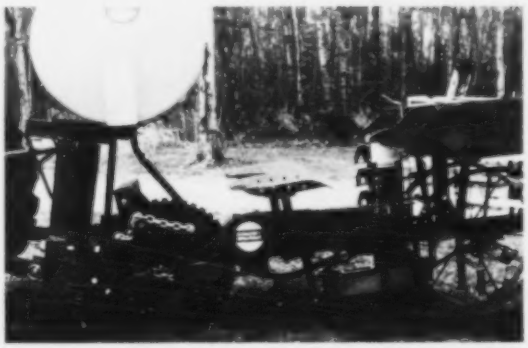
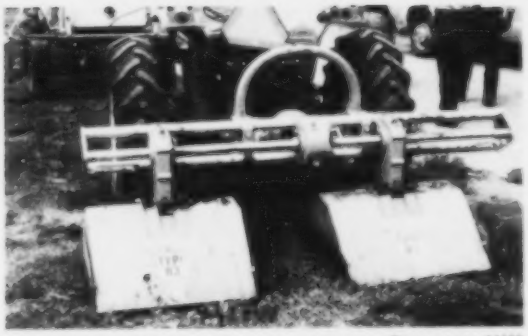


Photo courtesy AAFRD

Figure 35. *Strawberry planter*

Photo courtesy of "The Garden," Calgary, AB

Figure 36. *Straw spreader/applicator*



Photos courtesy AAFRD

***Figure 37**. Implements for mechanical tillage in strawberries*

Marketing Strawberries

On the prairies, most strawberries are marketed using a u-pick system. This method eliminates the need for hired picking staff, handling and grading facilities as well as shipping equipment.

A u-pick operation requires high quality, easily visible berries. In addition, fields must be neat, high yielding and free from weeds, diseases and insects.

Essential requirements for a successful u-pick operation:

- a location near an urban center, with an all weather road and easy-to-follow directions
- adequate and easily accessible parking and traffic flow
- advertising of the location with picking times, instructions, and helpful hints. (one good idea is personalized business cards with maps showing the farm location)
- excellent signage
- good telephone service (voice mail/answering machine, recording times and picking conditions)
- a website that provides maps and/or directions, information on picking times and seasons, contact information and miscellaneous information about the operation and associated activities

Drawing customers

A satisfied customer is the most effective advertisement for a u-pick operation. Good picking, fast checkout, fair pricing and friendly staff all contribute to good customer relations. Customers will be discouraged by line-ups and poor picking conditions, or if they are turned away because of poor crop information or lack of crop.

Attractive, legible u-pick signs are important to create a good first impression. Some provincial prairie grower associations offer u-pick signs for their members at a reasonable cost.

As competition for customers increases, growers should develop a positive farm identity that is distinguishable from other u-pick operations. Today's customers patronize u-pick farms with fresh quality product, friendly staff and a positive country image that provides a desirable experience.

All these qualities must be promoted in advertising and customer dealings. Growers attempting to base their reputations on lower prices will usually meet with poor economic returns in the long run. Service and quality are the two by-words of today's successful strawberry grower.

A website is now an essential tool for growers to use in promoting and creating a unique identity for their operation. A website provides information such as location, contact information, picking times and seasons. Besides the function of communicating basic information, a website can highlight the history of the business, outline additional activities an operation may offer that differentiate it from other operations and generally promote and advertise the business. The website can also be linked to other sites, such as those of grower associations.

Liability

Take steps to ensure the u-pick operation is protected from liability:

- Ensure that insurance policies adequately cover u-pick operations.
- Fence dugout areas and post signs warning of potential hazards.
- Store equipment and pesticides in a safe location and in a safe manner.

- Exercise extreme caution when applying pesticides on crops before harvest.
- Always follow recommended application rates and days to harvest. Many customers and young children may be sampling unwashed fruit in the field.

Time to pick

Yields are highest when ripe berries are harvested, so pickers should be encouraged to select fully ripened fruit. Ripe berries weigh more and are larger. In fact, there is a 76 per cent increase in berry size from the white to the fully ripened stage.

Customers should be invited to pick only when there are adequate numbers of ripe berries on the plants. Weather conditions determine the rate of fruit development and, thus, the number of times a field should be picked each week. In hot weather, fruit ripens faster and picking every two days may be required. When cool weather delays ripening, picking every three days will be sufficient.

The picking operation

Customers come to the service booth for directions to picking locations and to have their containers weighed or marked. Number the strawberry rows in the field to be harvested (see Figure 38).

Field supervisors should be instructed to help customers find the assigned row and ensure they pick only in that area. A rule of thumb for staffing is to have one field supervisor for approximately 40 u-pick customers.

The scale and check-in booth should provide protection from both the sun and the rain for equipment, staff and customers. The booth must also be adequately staffed to avoid customer line-ups. Post current price information in a prominent location to speed up customer checkout.

Many berries are sold by volume. A 4 L (0.88 gal.) basket has become the standard container size. Customers may also bring their own 4 L (0.88 gal.) ice-cream pails. Remember, berries should never be

Photos courtesy AAFRD

***Figure 38**. Strawberry field before/during picking*

picked into one container and then dumped into another. This process causes unnecessary bruising of the tender fruit and creates delays at the checkout.

Most u-pick fruit travels home in hot car trunks. Under these conditions, fruit freshness and quality are preserved better in shallow waxed cardboard containers. Growers can use advertising on the containers to promote their farms, and some offer refunds if the containers are recycled.

Sales etiquette

Staff members who meet the customers should be friendly, helpful and patient. Fair and friendly treatment promotes goodwill and is the best way of getting customers to return. Today's u-pick customer not only expects good service, but also demands it.

Sale of picked berries

When berries are picked for sale, provide a properly graded product. Pickers should be trained to harvest product that will meet all grade requirements. Cooling the product quickly to 1 to 2°C (34 to 36°F) is important for maintaining maximum shelf life.

Amenities

Clean washroom or toilet facilities must be available at all times. Where outhouses are used, provide hand-washing stands nearby. Locate these facilities at a site well away from the picking area, but also convenient for customers.

Many people regard a pick-your-own trip as a fun family outing that may include a picnic. It is worthwhile to provide a shady area with some tables as well as conveniences such as a soft drink dispensing machine. Play areas, sand boxes and swings for children could also be added.

Special customer services such as fishing holes, hiking trails, petting zoos and alternative crops can all enhance your farm's profile. To sustain continued growth, u-pick farms will have to provide more than fresh, high quality fruit for their customers.

Cost of Production

According to surveys conducted in Manitoba and Alberta, the variable costs for producing strawberries varies between $8,418 and $8,702/ha ($3,407 and $3,522/acre) per year for a 7-year production cycle (2 fallow years, a planting year and 4 picking years). This figure includes 212 hours of labour per hectare (86 hours per acre) per year.

Average provincial yields for established prairie growers range from 3,606 to 8,400 kg/ha (3,220 to 7,500 lb./acre) per year for the 3 picking years. Prices range from $3.30 to $4.63/kg ($1.50 to $ 2.10/lb.) for u-pick strawberries. Breakeven prices to cover variable costs can range from $1.10 to $2.91/kg ($0.50 to $1.32/lb.) for a 5,614 kg/ha (5,000 lb./acre) yield.

The rate of return varies greatly depending on the management practices used in individual enterprises. The potential rate of return per dollar invested should be similar to other businesses and greater than what is available in a short-term investment. Prospective growers should take the time to consult with their provincial farm management specialist to draft a budget tailored to their particular situation.

Factors that must be considered:

- winter injury losses (0 to 100%)
- no revenue for the first three years (two fallow years and one establishment year)
- high capital cost of irrigation system
- labour availability
- market saturation potential and marketing possibilities for excess fruit in a bumper crop year
- vulnerability of short harvest season (3 to 4 weeks)
- excessive rain or heat
- hail risk
- weed, insect and disease risks

New Developments

The most dramatic changes occurring in the small fruit u-pick trade are those related to the market. Growers located far from large urban centers are seeing a softening of the u-pick market demand. The new potential customer does not have the desire or the time to harvest and preserve fruit in the present u-pick marketing format. More emphasis will have to be placed on attracting new customers by providing entertainment and a fun family outing as well as high quality farm-fresh fruit.

Innovative and aggressive growers will survive and expand in this market. The busy family of tomorrow will be looking for fresh, good quality strawberries as well as the convenience of frozen fruit packs, jams and other processed products. The consumer will respond to a longer harvest period by purchasing fresh strawberry fruit more frequently.

The hotel, restaurant and institutional trade are a large, untapped market. These customers require high quality chilled fruit. New, well-storing fruit cultivars, innovative packaging (i.e. modified atmosphere packaging), controlled environment and forcing of day-neutral strawberries will be some of the ways to extend the period when fresh strawberries are available.

Today's consumers are eating 3 L (2.6 qt.) per capita as part of an improved lifestyle. This health consciousness is expected to continue and expand in the future. The modern consumer demands high quality fresh strawberries throughout the year. The challenge of today's strawberry growers is to meet most, if not all, of the demand.

On-farm Food Safety

Background

Consumers are concerned about the safety of their food and the risk that their fresh produce may be contaminated. Although the number of problems associated with Canadian fruits and vegetables is low, it is increasing. Growers must work to maintain the good reputation of their industry and ensure the safety of their products.

To reassure consumers and buyers, the Canadian Horticultural Council (CHC) developed a national, voluntary, on-farm food safety (OFFS) program. The program was developed in partnership with the Canadian Produce Marketing Association (CPMA), Canadian Food Inspection Agency (CFIA) and Agriculture and Agri-Food Canada (AAFC).

The *OFFS Guidelines for Fresh Fruit and Vegetables* manual focuses on potential sources of microbiological, chemical and physical hazards from field through to shipping. The manual contains the basic information horticultural producers need to develop a food safety program for their own farms. The guidelines can be found on-line at the CHC website. Click on Issues, Food Safety and "CHC's OFFS Guidelines."

The guidelines are based on the HACCP approach to food safety. HACCP (Hazard Analysis Critical Control Point) is a quality assurance program that ensures food safety and quality by anticipating and preventing hazards rather than relying on inspection and finished-product testing. HACCP was developed by the processing sector and has become internationally recognized as an effective means of managing food safety. OFFS is based on the HACCP approach of managing risk.

Program scope

The objective of the on-farm food safety program is to establish a system that will reduce the potential for chemical, microbial and physical contamination of strawberries and to provide a trace back that can limit the potential scope of an outbreak associated with the product.

Fresh produce is grown, harvested and handled under a range of conditions using a variety of agricultural inputs and technologies on various sizes of farms. Consequently, hazards vary significantly from one farm to another. Thus, each operation must consider the effect on food safety by each specific agricultural practice used. At a minimum, the production, harvesting and handling of strawberries must be conducted under clean, sanitary conditions that minimize potential contamination by hazards to human health.

Proper use and disposal of pesticides, cleaning materials, lubricants, etc. is the emphasis of the approach to minimizing chemical contamination. Properly cleaned and maintained equipment is the underpinning to the prevention of physical hazards. Attempts to minimize microbial contamination have focussed on certain critical areas, namely:

- water
- manure management
- worker hygiene
- field and facility sanitation
- transportation
- trace back

What is in the OFFS guidelines

The *On-Farm Food Safety Guidelines for Fresh Fruit and Vegetables* contains the basic information to help any producer develop a program to grow, harvest, pack, cool, store and transport most fruits and vegetables safely.

The document has been divided into several sections with each section covering a specific aspect of a produce operation, such as sanitation programs, agricultural chemicals or personal hygiene.

Because of the diversity within the industry, some elements may not apply to all operations; however, there are mandatory elements to the program that include the following:

- personal hygiene and sanitary working procedures
- cleaning and sanitizing program
- product traceability and recall program
- on-farm food safety program review (audits, validation or verification)

The guidelines present generally accepted Good Agricultural Practices (GAPs) based on current scientific knowledge. Because on-farm food safety is a relatively new area, the contamination risks and pathogen reductions are not fully understood; therefore, the present guidelines may not cover every issue related to food safety.

However, as the science evolves and new information becomes available, the CHC is committed to keeping the guidelines current and revising as necessary.

The guidelines also include an assessment workbook that helps producers identify the elements of their operations that may need more attention. Each question in the workbook is referenced back to a GAP for more detailed information. After conducting the self-assessment, each producer will have a framework upon which to build a food safety program specifically for the operation.

The OFFS guidelines are very generic so that they can be applied to any horticultural operation. Work is currently underway to develop a food safety producer's manual that focuses specifically on small fruit production. This manual will supplement the Guidelines by focusing on hazards specific to small fruits. It will include the "Must Do's," that is, the GAPs that must be implemented on the farm to ensure safe production of small fruits as well as practices that are recommended.

The guidelines and the accompanying producer manuals will provide enough details for producers to easily understand what is required for an effective on-farm food safety program. Information regarding record keeping and examples of records are also included in the producer manuals. Keeping records is very important when it comes to food safety. If a case of food borne illness were to occur, good records may help identify where and how the problem occurred.

OFFS guideline summaries

While the OFFS guidelines are voluntary, the principles outlined in them embody the demands of buyers and customers and represent sound, intelligent agricultural practices. Growers should carefully consider these guidelines and attempt to implement them into their operations. Some guidelines take time to implement fully. Conformance may make a difference between success and failure in the future.

The following are summaries of sections of the guidelines.

Premises (includes production sites)

The production of strawberries requires an uncontaminated environment. Direct and indirect contamination can occur from previous activities in the production fields or from animals and activities in adjacent lands.

Wherever possible, strawberry fields should be upstream from animal-oriented activities so that the crop is not in the direct path of contaminated runoff. Animal access, including pets, to the crop areas must be prevented or reduced to a level that does not pose a risk of contamination. Each field must have records of the crops and agronomic activities that have occurred at that location.

Premises also include buildings, areas surrounding the buildings and access to the buildings and production fields. The design and construction of buildings are important factors in preventing contamination. Buildings should be well constructed with materials that are durable and easy to clean and maintain. They must be properly maintained inside and out to prevent entry of contaminants and pests. Waste must be handled and stored in a manner that does not contaminate the berries. Roads and parking lots must be maintained to minimize or eliminate dust, which is a carrier of pathogens.

Soil amendments and fertilizers

Improper application (timing, rate) of fertilizers or application of materials not designated for agricultural use, e.g. calcium chloride, may cause chemical contamination of strawberries. Producers must maintain fertilizer application records.

Improper storage of materials can also result in contamination. Fertilizers should be stored in a designated area and under proper conditions.

Because of the risks inherent with compost and manure, if producers use these products, then they must know the source and how the product has been handled. Manure and compost must be applied so that they do not pose a risk; the timing and manner of application is crucial. Compost and manure must be stored in a designated area away from the production fields and other materials used in crop production.

Agricultural chemicals

Any pesticides used in the production of strawberries must be registered for that use and must be obtained from licensed suppliers. Producers must keep a list of agricultural chemicals received and amounts stored.

Pesticides must be used safely according to the label instructions. The recommended interval before harvest must be followed to prevent the risk of chemical residues within the fruit. Applicators should be provided with the necessary equipment and proper training. Producers must keep spray records.

Pesticides should be stored in a designated area and in a manner that ensures no cross-contamination or risk of contaminating the berries. Application equipment must be properly cleaned and maintained. Chemical containers must be disposed of according to provincial regulations.

Water

Water is a crucial input for strawberry production, but it can also be a direct source of contamination. Because of water's many uses, including irrigation, chemical and fertilizer application, frost protection and sanitation, water quality is very important to the production of safe berries.

Producers need to assess the risk of contamination, especially if using surface water, and determine what preventative methods need to be employed to safeguard the quality of their water.

Harvest containers

Containers used for harvesting strawberries must be made of non-toxic materials that are easy to clean. Recycled containers should be in good repair and properly sanitized. Harvest containers should never be used to store or transport materials other than the harvested berries. The containers should be stored in a location that presents a minimal risk of contamination.

Equipment and tools

All equipment, including that for production, transportation and cleaning, and all working tools must be constructed of materials that will not contaminate the crop. Wood surfaces should be avoided wherever possible. The website of the Canadian Food Inspection Agency, Agriculture and Agri-Food Canada, contains a listing of accepted materials and products.

Dirty, poorly maintained equipment and tools can be a source of contamination. Growers must have cleaning and preventative maintenance programs for their equipment and tools. Records of these activities must be maintained. All maintenance materials such as lubricants and other chemicals must be properly stored and disposed.

Any equipment that requires calibration, e.g. sprayers, must be properly calibrated according to manufacturers' instructions, and the appropriate records must be maintained.

Transportation and storage

This section likely won't apply to u-pick operators because of the nature of their business. However, strawberry growers who sell to food service, retail or at farmers' markets will be cooling, storing and transporting their berries. During cooling and storage, berries must be handled in a manner that minimizes damage, contamination and microbial growth. Strawberries should be stored at 1 to 2°C (33.8 to 35.6°F) to prevent microbial growth and maintain quality.

Proper transportation is critical to the safety of perishable fruits and vegetables. Transportation equipment must be clean and should be inspected before loading the berries. Proper temperatures should be maintained during transit.

Cleaning and sanitation

Good sanitation practices provide the foundation for a sound food safety program and are a required element to the program. A sanitation program includes cleaning and sanitation. Cleaning is the removal of dirt, dust, organic matter and foreign materials. The purpose of sanitizing is to kill and remove microorganisms. Inadequate cleaning prevents effective sanitizing.

Cleaning and sanitation programs need to be developed and implemented for premises, equipment and tools as well as containers. Records for these activities must be kept.

Cleaning and sanitizing products must be used and stored properly. Workers should be trained to implement the sanitation program effectively.

Personal hygiene

Pathogens can be transmitted in a number of ways, but the most common is human cross contamination Workers need to understand the importance of basic hygienic conditions and practices as well as their responsibility to ensure that fresh produce is handled properly.

All employees should have a good working knowledge of basic sanitation practices and hygienic principles. Employers need to develop training programs. The method of training can vary with employees and will depend on the workers' requirements. Training records need to be maintained.

Producers must provide staff with washroom and hand washing stations convenient to their work areas. The facilities need to be adequately equipped with water, liquid soap, single use towels and waste containers. They also need to be kept clean. U-pick operations should be equipped with clean, well-stocked washrooms for customers.

In addition to personal hygiene, workers must also follow good handling practices. Advocating changes in the personal behaviours of workers, such as using hair restraints or not wearing jewellery when in direct contact with food, may create challenges for farm managers, but are actions that must be considered.

Pest control

Producers must develop and implement an effective written pest control program. Every attempt must be made to prevent pests, including pets and birds, from entering buildings. The grounds around buildings must be maintained to discourage pest activity, i.e. keep grass cut to discourage mouse activity. Waste and garbage must be properly stored and removed.

Producers must also be actively monitoring for pests to assess the effectiveness of their program. Setting out traps after seeing the droppings is too late; prevention is the key.

Records of monitoring and control activities must be kept.

Product traceability

Despite the best efforts, accidental contamination on the farm is possible. Being able to identify and trace the contaminated product is a valuable part of a food safety program. Thus, the horticulture OFFS program requires all producers to have an identification system that would enable product to be traced back through all stages of production, storage and packing. Producers should also have a system in place to handle complaints relating to product hygiene and safety.

As strawberries make their way from farm to table, there are a number of possibilities for the fruit to become contaminated. Each person at every step in the supply chain needs to do his or her part to reduce the risks. Growers need to be aware of the hazards lurking within their operations. By implementing a food safety program, growers are not only protecting public health, but they are also safeguarding their business.

Accessing the OFFS guidelines for fresh fruit and vegetables

For more information about the horticulture on-farm food safety program, contact your provincial association or the Canadian Horticultural Council (see *Resources* section).

As mentioned, the OFFS guidelines can be accessed on-line at the CHC website by clicking on ISSUES, Food Safety and on "CHC's OFFS Guidelines."

Pesticide Safety and Management

Consumer consciousness of pesticide use in farming is a major grower concern. Surveys have shown that as much as 80 per cent of the population is concerned about pesticide safety on the food products they buy. U-pick operations can improve consumer buying confidence when consumers can meet growers and be assured that their pesticide practices are safe.

Growers will be faced with increased public pressure to control and minimize the use of pesticides in crop production. Alternative management techniques will be necessary to strengthen consumer confidence. Growers should also help dispel misinformation about pesticide residues. For example, it is estimated that the average American citizen is exposed to 46 micrograms of potentially carcinogenic pesticide residues in food and water daily while a single cup of coffee contains about 500 micrograms of potential carcinogens.

Consider the following factors when selecting pesticides for crop management.

Choosing appropriate pesticide products

Many pesticides are on the market; however, it is critical to use only those products registered with the Pest Management Regulatory Agency (PMRA) for the specific crop and pest (See *Resources* section for contact information). The product label should always be consulted for detailed information about the nature of the product, application and safety guidelines, recommended application rates and any use restrictions.

While many products are registered for use across the prairies, some geographic restrictions apply for some products. Growers should contact their provincial specialists or pesticide information resources for current information (See *Resources* section for details). Pesticide companies may also provide specific information to growers on specific products.

Toxicity of the chemicals

Chemicals with high LD_{50} ratings are less hazardous to the grower and the environment. For example Malathion, which has a LD_{50} rating of 1,200, is not as toxic as Guthion, which has a LD_{50} rating of 7. Only use chemicals registered for use on strawberries and follow the label specifications for rates, days to harvest waiting periods (pre-harvest interval) and other conditions. Failure to follow these basic rules of pesticide safety exposes the grower and industry to undue liability and increases the risk to the consumer.

Proper safety equipment

Protective devices such as approved gloves, a recommended respirator and approved clothing should be used when handling pesticides. Insecticides can enter the body through the mouth (orally), through the skin (dermally), or through the lungs (respiratory system).

Poisoning

Know what to do in the event of a spill or accidental poisoning. Review procedures on the container label before handling a pesticide.

Safe storage and disposal of containers and unused material is important to protect children of u-pick customers from accidental exposure.

Chemical application

Pesticide application through the irrigation system is not recommended because coverage is not efficient. As well, there is a danger of water supply contamination because irrigation water containing pesticide can flow back into the water source if main line pressure drops suddenly.

Contamination by back siphoning can be avoided by using a reduced pressure back-flow preventer. This device is installed in the supply line at a point well ahead of the material injection point. Similar precautions to control back-flows should be observed when filling sprayers from lakes, rivers or streams. Note: before installing a reduced pressure back-flow preventer, consult water authorities regarding local regulations.

Observe the waiting period specified on the label before entering treated fields. If the waiting period is not observed, chemicals on the foliage can be absorbed through worker's skin or lungs.

Effectiveness of spraying

Several factors influence the effectiveness of pesticide application. These include the correct diagnosis of the problem, appropriate spray intervals and time of application, resistance of the pest and weather conditions. A water pH of 8 or more can also affect the efficiency of certain pesticides.

High spray pressure is essential for full coverage of the large foliage area of a strawberry row and to ensure penetration through the canopy. Pesticides must be applied in at least 1,123 L/ha (100 gal./acre) of water at a pressure of 1,379 kPa (200 psi). Field sprayers with low volume and pressure capability are not suitable for spraying insecticides and fungicides on strawberry crops.

Rely on natural enemies where possible. By limiting the number of sprays and ensuring sprays are applied in the most effective manner, you will conserve natural enemies and reduce the likelihood of secondary pest outbreaks.

For greater coverage, use a chain ruffler rather than a solid bar. Nozzles should be set to a point slightly forward, so material is applied immediately behind rather than in front of the chain. This nozzle position will provide increased coverage of the upper leaf surface and twice the coverage of the underside.

Strawberry Disease and Pest Problems

The ability to recognize and correct production problems early is essential for a successful strawberry operation. Shortcuts in preparing and maintaining a strawberry field will often result in serious problems later in the production cycle. Conduct frequent field inspections on a **minimum** weekly basis during the early portion of the production cycle. Weak stands of strawberries are more prone to insect and disease attack and, therefore, should be monitored more frequently.

Nutrient deficiencies can contribute to disease and insect pest problems. Plantings should be monitored regularly for deficiency symptoms and deficiencies corrected, where possible.

In the production season, fields should be examined for off-type plants. These plants should be pulled, examined and removed from the field. If the problem cannot be identified, call the local authority for assistance.

Pesticides can help control insects and diseases, but should only be used when necessary to prevent a loss of income. It may be preferable to adopt an integrated pest management strategy that combines the monitoring of pest populations with the use of injury threshold levels. The timing of any pesticide application is also important to prevent economic loss for the current crop and for the life of the planting.

For pesticide recommendations, consult current pest control product information for your province. Also, pay careful attention to the information on the product label, including safety precautions, mixing instructions, application rates and pre-harvest intervals.

Insect control begins with sanitation. Isolating new and old fields reduces the risk of insect migration to new crops. Weeds often harbour insects that attack strawberries during flowering and fruiting periods.

The use of certified strawberry plants is a significant part of a disease control program.

Problem identification

Knowing the characteristics of an insect or pathogen is the key to field diagnosis of strawberry problems. For example, wilting of new leaves in the crown can be a telltale sign of early cutworm damage or may be an indication of root rots or winterkill. Similarly, white powdery patches on the lower leaf surfaces are typical signs of powdery mildew infection. Close inspection can determine which is the cause, and quick action at this stage can minimize damage to the planting.

However, in some cases, corrective action must be taken before obvious signs of injury appear. For example, the tarnished plant bug can cause serious damage while the plant is still in the blossom stage, but injury does not become obvious until after the insect has left the blossom.

Therefore, it is important to monitor the tarnished plant bug population with traps or frequent field inspections during the blossom stage. Average tarnished plant bug levels of 0.15 nymphs per flower or higher warrant an insect control measure for aesthetic purposes and 0.95 for yield purposes.

Insect cycles and populations are affected by weather. For example, normal hatch times can occur earlier during a mild spring. If above-normal temperatures prevail during the production cycle, the crop may have to be monitored and sprayed more frequently.

Physiological Disorders
(Abiotic, Non-infectious Diseases)

Strawberry plants are affected by a number of problems that are not caused by insects or infectious diseases. These problems are physiological in nature and may be due to deficiencies or excesses in fertility, changes in environmental conditions or other factors.

Disorders attributed to nutrient deficiencies

Nutrient deficiency or toxicity can appear as a range of symptoms in plants, including leaf discolouration, tissue death or deformity. Plant tissue analysis can be used to identify a fertility problem. Some deficiencies can be corrected by fertilizer application; however, it is important to catch deficiencies early to minimize the impact on yield and plant vigour. See the following colour image section for examples of a number of nutrient deficiencies (Figures 39 to 43).

Tip burn

Tip burn is the result of a temporary calcium shortage. This condition occurs on the leaves of young strawberry plants during periods with hot days and cool nights or after a frost to young, unfolding leaves. The symptoms are plants with slightly malformed leaves with dry leaf margins. This condition is not usually considered serious. Application of calcium chloride in a water solution at 1.12 kg/1,123 L/ha (1 lb./100gal./acre) as a foliar spray may be helpful.

Yellowing or chlorosis

Red Coat and certain other cultivars appear to be more sensitive to yellowing or chlorosis, which produces a fading or yellowing of the foliage. Chlorosis development is influenced by the genetic makeup of the cultivar, soil alkalinity and salinity, topography and soil aeration. Temporary yellowing can occur on waterlogged soils after long periods of irrigation for frost control or excessive rainfall. Yellow strips of "mother plants" frequently occur during growth early in the season. These plants generally have suffered winter injury to the root system.

In some severe cases, the yellowing can be corrected by incorporating an iron chelate into the soil at the rate of 14.3 kg/ha (13 lb./acre) of actual iron (see Figure 43).

Disorders attributed to adverse environmental conditions

Wind damage to the foliage and fruit

Wind damage can result from poorly sheltered strawberry plantings. Exposure to strong winds and wind borne soil particles will cause "tar spots" on the leaves and stems. This damage is caused by a chemical change in the cell contents when they are exposed to air. The reaction is similar to exposing the surface of a sliced apple to air. Wind damage can reduce plant vigour as well as the quality and shelf life of fruit from young plantings.

Sunscald of fruit

When berries receive too much exposure to the sun, the skin of the fruit can break down or soften, causing sunscald. The main symptom is a discoloration of the fruit surface ranging from pink to off-grey (see Figure 44). Fruit not protected by a good foliage canopy are prone to this condition. Berries on the south and west sides of rows are especially vulnerable to damage.

Stunting and reduced leaf development

Winter injury to the crown and/or roots is often the cause if stunted and reduced leaf development symptoms are exhibited over the whole field. Repeated freezing and thawing or insufficient snowfall to cover the plants often precedes this condition. Cutting the plant crown vertically and examining the tissue for brown areas, indicating freezing injury, can verify the problem. Plantings that incur winter injury early in their life cycle rarely recover. Early plowdown of the planting may have to be considered.

Misshapen fruit

Strawberry fruit can be deformed or misshapen due to a number of factors. Deformed fruit showing lines or folds along the berries can be caused by 2,4-D drift at the time of fruit bud initiation. Even a minimal amount of herbicide drift can result in abnormal fruit.

The period of sensitivity for June bearing strawberries is usually late fall. Day-neutral strawberries are susceptible any time during active plant growth. Other causes of deformed fruit include frost, nutrient deficiencies, insect damage, grey mould and genetic abnormalities.

Cat facing is a very common problem in strawberries and is characterized by partial or apical seediness. This condition may be caused by insect damage, frost injury, nutrient deficiencies, poor pollination due to environmental conditions or disease and viral infections.

Color Section 2

Photo Courtesy AAFRD

***Figure 27**. Established strawberry field after mowing*

Photo Courtesy AAFRD

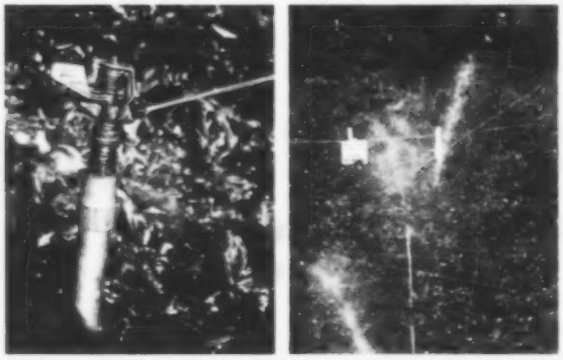
***Figure 28**. Strawberry field after renovation*

Photo Courtesy MAFRI

***Figure 31**. Frost damage on strawberry leaves*

Photo Courtesy AAFRD

***Figure 32**. Frost damaged strawberry flowers – note blackened centres*



Photos Courtesy AAFRD

***Figure 33**. Sprinklers for frost protection*

Photo Courtesy AAFRD

***Figure 34**. Ice-coated strawberries*

Photo Courtesy MAFRI

***Figure 39**. Nitrogen deficiency in strawberry leaves*

Photo Courtesy MAFRI

***Figure 40**. Potassium deficiency in strawberry leaves*

Photo Courtesy MAFRI

***Figure 41**. Sulphur deficiency in strawberry leaves*

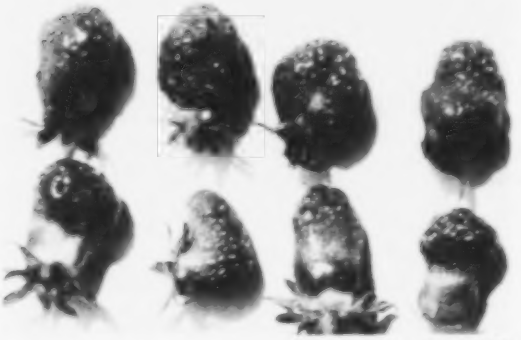


Photo Courtesy MAFRI

***Figure 42**. Boron deficiency in fruit*

Photo Courtesy MAFRI

***Figure 43**. Iron deficiency in strawberry leaves*

Photo Courtesy C.C. Peters

***Figure 44**. Sunscald damage on strawberry fruit*

Diseases Caused by Fungi, Bacteria or Viruses
(Infectious/Biotic Agents)

The diagnosis of infectious plant diseases can be challenging and often requires a knowledge of both pathogen biology and the influence of weather conditions upon disease development. Disease can only occur when suitable environmental conditions, a susceptible variety and a plant pathogen interact in a specific fashion.

Chemical controls (fungicides, bactericides and fumigants) are often necessary to prevent or control many strawberry diseases, and most should be applied before disease development. Recognizing which factors promote disease outbreaks will help ensure a healthy, productive strawberry crop.

Anticipating disease problems before an outbreak may reduce disease impact on fruit yield and quality. Recording information on disease distribution within the field will be of great value in planning a strategy to manage diseases. For example, knowing whether the disease is clumped in small groups, if individual plants are diseased, or whether large areas of the field have plants with similar symptoms can allow you to make the most efficient use of your time when managing strawberry diseases.

Moisture on plant surfaces is necessary for the development of most above-ground diseases. Generally, moist periods followed by higher temperatures are often conducive to the development of leaf and berry diseases, but this situation will vary with pathogen. Recording the frequency of rainfall, the occurrence of long dew periods, frosts, and unusually high or low temperatures will provide an idea of the risk of future disease outbreaks.

Moisture (dew) on plant surfaces is further influenced by slope of the land, as colder air tends to move to lower areas. Portions of fields that are shaded during the morning will usually have lower temperatures and longer foliage drying times, as will fields that are sprinkler irrigated.

Usually, the result of the pathogen damage (symptoms) is observed first, as opposed to the pathogen itself (with the exception of powdery mildews). Symptoms may be leaf spots, changes in the colour of plant parts, wilting of leaves, stunting, or distortion of plant tissue and blossom or fruit rots. Descriptions of the more common disease problems are described in this section. See the following colour image section for pictures of disease symptoms (Figures 45 to 52).

Diseases that attack foliage

Strawberry leaf fungal diseases are not usually a problem in most years in the drier regions of the prairies; however, they are common in wetter years and in wetter regions, such as Manitoba.

After renovation, a healthy foliage canopy must be maintained for fruit bud set and the storage of winter food reserves. The risk of strawberry leaf and fruit diseases is reduced with renovation and the removal of tops from the field. Tops are an inoculum source that may cause new outbreaks on new foliage in the following year under suitable conditions.

Leaf scorch (*Diplocarpon earlianum*)

Symptoms/Disease Cycle

Leaf scorch can greatly reduce plant vigour and increase the susceptibility to winter injury or drought stress. Leaf and root growth can be significantly reduced.

Similar in appearance to leaf spot, leaf scorch is best identified by leaf symptoms. Symptoms first appear as small, irregular, purple-brown spots ranging from 1 to 5 mm (1/32 to 13/64 in.). In contrast to common leaf spot (*Mycosphaerella fragariae*) lesions, the centers do not turn white or grey (see Figure 45). Under high disease pressure, numerous spots on leaves aggregate, and reddish-purple tissue may be visible between the spots.

As the disease develops, diseased leaves dry and turn brown with curled edges, giving the leaves a scorched appearance. Petiole symptoms appear as long, sunken, reddish-purple lesions. Severe lesions can girdle the petiole, killing the leaf.

Symptoms may also be observed on flower parts and fruit. When the calyx is affected, market value may be decreased as the "brown capped" fruit look less palatable than fruit with healthy green calyxes.

Factors that favour the development of this disease

- plants that are wet for extended periods
- poor air drainage within the planting
- excessive nitrogen
- older plant stands

Control/Management

Cultural management of leaf scorch can be accomplished in a number of ways. Any method targeted at reducing moisture on the plant and levels of the fungus will reduce the likelihood of severe leaf scorch symptoms.

Practices such as planting in areas with good air movement and minimal shade, avoiding the application of supplemental nitrogen in the spring, scheduling sprinkler irrigation to avoid long wetness periods, removing all foliage and crop residues after picking or at renovation and frequent (every three years) renewal of strawberry plantings will reduce the impact of leaf scorch.

Common leaf spot (*Mycosphaerella fragariae*)

Symptoms/Disease Cycle

Common leaf spot first appears on leaves as purplish spots that resemble leaf scorch. Later, these spots enlarge to a diameter of 3 to 6 mm (1/8 to 1/4 in.). The centers become grey or white with reddish to purplish borders (see Figure 46). Leaf petioles or stalks, stolons, runners and, to some extent, calyxes (caps or hulls) may also be attacked.

Plants are mostly susceptible early in the growing season and in late summer, especially where growth is very succulent. The leaf spot fungus may also attack the fruit and cause black seed. Spores of the fungus form on the spots and are spread by rain, hands, tools and clothing when plants are wet.

Factors that favour the development of this disease

- susceptible cultivars/varieties
- succulent growth, caused by excessive fertility
- handling during wet conditions

Control/Management

Some cultivars are more susceptible to leaf spotting than others. Disease-free stock should be used to establish new plantings. Timely fungicide sprays are also an effective method of control.

Powdery mildew (*Sphaerotheca macularis*)

Symptoms/Disease Cycle

Powdery mildew can affect all above-ground parts of the strawberry plant. Leaves, flower calyxes and fruit all support mildew growth. Infected leaves curl upward, become purplish on the underside and, in

severe instances, develop badly burned areas at the margin. A white, powdery fungal growth may be seen on the underside of severely affected leaves. Powdery mildew develops in the spring and fall (see Figure 47).

Infection begins in the spring soon after plant growth starts. The spread is gradual and may not be noticed until most plants in the field are infected. If a severe outbreak occurs before picking, the fruit yield may be greatly reduced. Symptoms are most noticeable on warm, dry days.

Factors that favour the development of this disease

- poor airflow due to dense shelterbelts
- warm, dry days

Control/Management

Any practice that favours or creates conditions of high humidity in strawberry plantings will favour the development of powdery mildew. These conditions should be avoided or corrected. Timely fungicide sprays are an effective method of control, especially when used in conjunction with growing varieties that have a high level of resistance to powdery mildew. The removal of infested crop debris in the fall may reduce carryover of the pathogen to the next crop.

Diseases that attack fruit

By far the most important strawberry diseases are the fruit rots/decays caused by several fungi, which are capable of destroying a large percentage of the fruit. Picking and packing are also more costly when these diseases are present in the field. Losses will vary with time and location as well as weather conditions from first bloom through harvest.

Anthracnose fruit rot/black spot (Colletotrichum fragariae, Colletotrichum gloeosporioides, Colletotrichum acutatum)

Symptoms/Disease Cycle

Light brown, water-soaked spots form on ripening fruit and rapidly develop into firm, round lesions, which usually turn dark brown to black, but may remain tan. Lesions remain firm and enlarge until the entire fruit is affected (see Figure 48). Affected fruits eventually dry up and mummify. Lesions on green fruit may be restricted to single achenes, which turn black and become slightly sunken. As the fruit develops, a sunken lesion appears at the infected achene.

Factors that favour the development of this disease

- conditions where rain/water splashing is likely (plastic mulch)
- short or no rotation between strawberry crops
- presence of diseased debris (fruit or plants) in the field
- hot, wet weather before or during bloom and through to harvest

Control/Management

Plastic mulch used in annual systems may increase water splashing and spread disease more rapidly. Use other types of mulches around plants to prevent rain splash of the spores, and remove debris from the field after renovation. Severe outbreaks from year to year may necessitate taking the field out of strawberry production for several years before replanting. Fumigation of infected ground may be worth considering, if economical. Purchase plants from an accredited nursery.

Anthracnose can overwinter on fruit and plant debris. Removal of this material lessens the risk of inoculum carryover. Hot, wet weather before and during bloom through harvest are ideal conditions for anthracnose to develop.

Grey mould (Botrytis cinerea)

Symptoms/Disease Cycle

Grey mould is very common and often causes serious losses in strawberries, both before and after harvest. If berries infected with grey mould are eaten, customers usually complain of off-flavoured fruit.

This disease affects blossoms and blossom stalks of green or ripe fruit. Infections usually start in the

blossom and may destroy the entire blossom stalk. Blossom infection can enter a dormant period in the calyx or hull, later causing a fruit rot as the plant develops.

Botrytis rot is soft and light brown. The fungus may spread to other blossoms and berries through direct contact or by spores that are blown or splashed. A fine grey, powdery growth develops and infects blossoms, fruit stalks, fruit and other plant parts (see Figure 49). Fruit rot and grey mould may appear on the picked fruit after one or two days.

Factors that favour the development of this disease

- shade or dense foliage in the bed
- extended periods of excessive moisture
- cool spring and summer temperatures and high humidity from frost control techniques, general irrigation and natural rainfall
- factors that produce soft fruit, such as high applications of nitrogen during fruiting

Control/Management

Apply protective fungicides at bloom and continue until harvest if cool, wet conditions prevail. Appropriate pre-harvest intervals should be observed. Black plastic mulch dries off faster than straw and, as a result, lessens the likelihood of mould development.

Rhizopus rot/leak *(Rhizopus stolonifer)*

Symptoms/Disease Cycle

Although primarily a post harvest or storage rot, rhizopus rot, or leak disease, can occur on ripe fruit in the field.

Infected fruit becomes slightly discoloured, gradually turning light brown. The fruit rapidly softens and collapses as juices leak out of the berry. Under humid conditions, the fruit is soon covered with dense, cottony white strands (known as mycelium) with blackened ends (spore heads).

Rhizopus is unable to infect undamaged fruit, requiring a wound to gain entry. Spores are spread easily in the wind and may be distributed by insects. This fungus is very common and probably lives on crop debris on and in the soil between seasons.

Factors that favour the development of this disease

- damaged or weakened fruit
- presence of diseased debris in and around the field
- warm storage temperatures

Control/Management

Some varieties have been found to be resistant to Rhizopus. Rhizopus rot can be controlled by rapidly pre-cooling strawberries immediately after harvest and then maintaining storage temperatures below 6°C (42.8°F).

Tan-brown rot *(Hainesia lythri)*

Symptoms/Disease Cycle

Tan-brown rot is considered a disease of plants in the field, but it may occur on fruit after harvest. It can be a concern in warm, humid areas of the prairies, particularly in parts of Manitoba.

Initially, small, light brown and slightly sunken spots appear, expanding slowly on green fruit, but progressing more rapidly on ripe fruit. The infection can go deep into the fruit, with the core taking on a dry and spongy texture. Weakening of the area around the diseased portion of the fruit allows for the removal of the entire affected area, comparable to a cork being pulled out of a bottle.

This unusual feature of the disease is the key diagnostic symptom of tan-brown rot, which makes identification relatively easy. The fungus has also been associated with the deterioration of strawberry roots.

Little is known about the disease cycle of tan-brown rot. The fungus does require wounds to enter the fruit and tends to appear after prolonged rainfalls. The fungus can infect a number of plant species, which can allow the fungus to survive in the absence of strawberries. Strawberry crop debris may allow the fungus to survive through the winter.

Factors that favour the development of this disease

- warm, humid conditions
- presence of diseased debris or alternate host plants in or around strawberry plantings
- things that favour rain/water splash

Control/Management

Cultural practices include the removal of weeds and crop debris as well as the mulching of plants to reduce splashing of rain or irrigation water. Currently, no fungicides or resistant cultivars are available to manage this disease.

Other fruit rots

Several minor rots can attack fruit and cause significant damage to certain day-neutral strawberry cultivars under ideal environmental conditions.

Leather rot *(Phytophthora cactorum)*

Symptoms/Disease Cycle

Fruit becomes dull or lifeless in appearance with color ranging from bleached to purple to nearly normal. Fruit is discoloured internally and externally, and it usually has a dry leathery appearance.

Factors that favour the development of this disease

- poorly drained fields
- insufficient straw mulch under the plants, resulting in excessive contact between fruit and soil

Control/Management

The occurrence of this disease can be minimized by selecting well-drained fields for planting and through the use of mulches to keep berries from touching the soil.

Soil borne diseases/diseases that attack the root system

The effect of diseases on underground portions of the plant can often be seen by the response of the aboveground portions of the plant. Plants that have severe root damage tend to appear stunted and have reduced growth rates, wilting or dried out leaves.

If plants appear to be reduced in size, pulling the plant up and checking the roots can quickly indicate if there is a problem. Healthy strawberry roots should be yellow-white with a number of root hairs. Swollen, stunted, discoloured roots are an indication of a problem.

Black root rot *(various pathogens, notably Rhizoctonia fragariae, Pythium spp., Idriella lunata, Cylindrocarpon destructans)*

Symptoms/Disease Cycle

Black root rot is a term given to the destruction of strawberry roots, the specific cause of which is still uncertain, but it appears to be a combination of environmental factors and fungi either acting alone or in combination. The fungus *Rhizoctonia fragariae* appears to be the most widespread black root rot pathogen.

Extensive death of feeder rootlets, deterioration and blackening of structural roots as well as declining plant vigour and productivity are the most prevalent and typical symptoms of black root rot.

Factors that favour the development of this disease

- winter injury
- poorly drained soils
- excessively acidic or alkaline soil conditions
- damage from soil fungi or root lesion nematodes (*Pratylenchus* spp.)

Control/Management

Management of black root rot can be very difficult, as any form of stress on the plant can increase the likelihood of damage.

Red stele root rot *(Phytophthora fragariae var. fragariae)*

Symptoms/Disease Cycle

Red stele root rot is caused by a soil borne fungus. Plants may be stunted and wilt in hot weather. Young leaves take on a bluish-green appearance, while older leaves appear tinged with red, orange or yellow. Within a field, the symptoms tend to be clumped in irregular patches, especially in lower areas of the field.

The key symptom that assists with the recognition of this disease is the reddish discolouration of the vascular system (stele), apparent above the decaying root tip, when the root is cut lengthwise. As the disease progresses, the root turns brown and the reddish stele becomes less distinct.

The youngest roots rot from the tip back to the plant crown, destroying lateral roots in the process. The red stele symptom is not observed in older suberized roots, but may be observed on any lateral roots present. When the disease has taken hold, plants will produce no fruit or fruit of reduced size. If the root rot becomes severe, the entire plant may die. Associated with wet and moist soils, infection tends to occur at lower temperatures (about 15°C or 59°F), although the above-ground symptoms are much more apparent with the onset of higher temperatures (above 20°C or 68°F).

Factors that favour the development of this disease

- plants are grown for multiple seasons
- wet soil conditions and favourable temperatures
- the younger the plants are when they are infected, the greater the impact on plant growth
- susceptible varieties, strawberry varieties range from resistant (only slight damage to a few root tips) to highly susceptible (the root system is destroyed) (see Figure 50).

Control/Management

Disease-free planting stock should be used to establish new plantings. Select well-drained fields to minimize the risk of water logging.

The movement of planting material and infested soil (via shoes or farm machinery) can spread the pathogen throughout the field and to other strawberry fields. Disinfecting equipment is advised to prevent the movement of the fungus to other fields. Fungicide drenches can be applied where the risk of infection is high.

Verticillium wilt *(Verticillium albo-atrum, V. dahliae)*

Symptoms/Disease Cycle

The fungi responsible for verticillium wilt of strawberry can cause disease in a very wide range of crops and weeds, most notably tomatoes, potatoes, and alfalfa. Even in the absence of a suitable host, soil borne propagules (small darkened structures known as sclerotia) can survive and cause disease for almost a decade.

Sclerotia can be spread from field to field by water or wind, on infected planting stock or plant debris (including underground portions and stems of many host plants). There are differences between the two species, but both can cause significant damage. The long-lived nature of the fungus can take fields out of production for long periods.

Strawberry plants are affected to the greatest extent during their first year of growth. Symptoms appear in late spring, and may continue throughout summer and fall, especially if periods of environmental stress interrupt mild conditions.

When a stem is cut, the vascular system around the crown and within the roots will appear brown when this disease is present. Browning at leaf margins occurs on the outer leaves, which eventually collapse. Inner leaves are stunted but tend to remain green (or take on a blue tinge) and turgid until the plant dies, a symptom that can distinguish verticillium wilt from the root and crown diseases caused by species of *Phytophthora*, in which young as well as mature leaves wilt (see Figure 51).

The distribution of wilt can range from single plants side by side with healthy ones, small scattered patches or large areas encompassing much of the field.

The use of field symptoms alone is not always reliable for the diagnosis of verticillium wilt, and laboratory testing may be required. Testing can be done, for a fee, by a number of plant health laboratories (see *Resources* section for details).

Factors that favour the development of this disease

- environmental stresses, such as sudden onset of high temperatures, high light intensity, or drought
- generally, lush plants grown with high nitrogen are more severely affected than plants with moderate nitrogen
- planting in fields that have had problems with this disease in the past
- planting susceptible varieties

Control/Management

There are strawberry varieties that have varying degrees of tolerance to verticillium infection. If fields are known to have had problems with verticillium previously, planting tolerant varieties is recommended. The fumigation of fields in the year before planting is also an effective way to reduce the population of the sclerotia in the soil.

Other strawberry diseases

Storage mould

Symptoms/Disease Cycle

This mould can kill new plants and is caused by several organisms. Symptoms include rotting of tissues and the development of various moulds.

Factors that favour the development of this disease

- plants are diseased when they arrive from the supplier
- poor storage conditions (uneven temperatures, inappropriate humidity in storage)
- damaged plants

Control/Management

Do not plant mould-infected plants. Source plants from a reliable, recognised supplier.

Diseases caused by viruses and phytoplasmas (virus-like pathogens)

Diseases caused by viruses and virus-like pathogens can vary considerably in the expression of symptoms. They can be easily confused with nutrient deficiencies, water stress, chemical injury, insect damage and temperature stress. Many viruses are often symptom-less or have no distinct symptoms. The only indication of viral infection may be a reduction in vigour, stunting or reduced yields.

In cases where the disease is not very severe, the effect may be negligible in the current season, but more apparent in subsequent years. Reductions in yield from year to year could suggest a virus or phytoplasma-related problem.

Many aphids and some nematodes are capable of carrying (vectoring) viruses, while phytoplasmas (most notably aster yellows phytoplasma) are vectored primarily by species of leafhoppers.

Currently, no practical method of curing virus or phytoplasma-infected strawberry plants exists. The best management practice is the use of certified virus-free planting material, in conjunction with management of the insect vector. Vector control can be achieved through pre-plant chemical treatment of soil borne nematodes and post-plant chemical treatment of leafhoppers and aphids.

Virus diseases

Symptoms/Disease Cycle

A number of viruses can afflict strawberries, but little is known about their distribution across the prairies. Aphids spread the majority of viruses; however, infected planting stock can also serve as a means of spreading viruses over longer distances. If plants are not purchased from a reputable strawberry nursery, virus problems may be observed.

If plants in your field appear to be stunted, show very low vigour, or appear yellow, a number of environmental or nutritional explanations could be applicable. If there are no apparent other causes, a virus could be possible. Depending on how widespread the problem is, a virus test may be worthwhile. For further information on where a strawberry plant can be sent for virus testing, please contact your provincial agricultural extension service. Commercial labs can perform this service for a fee.

Wild strawberries can act as a potential virus source, which could spread viruses to cultivated varieties. Cultivated strawberry fields located near large native stands of strawberries may experience more significant virus-related problems.

Factors that favour the development of viruses

- presence of infected plants in a planting
- presence of insect vectors
- planting non-certified plants
- presence of wild strawberries in proximity to a planting

Control/Management

Disease-free stock should be used to establish new plantings. Avoid planting near wild stands of strawberries or remove any wild strawberries in the vicinity.

Control of insect vectors is also an important control tool, if viruses are present.

Aster yellows

Symptoms/Disease Cycle

Aster yellows is caused by a phytoplasma, a micro-organism with some properties of a bacterium, which cannot, however, be grown in culture like many fungi and bacteria.

Diseased leaves appear chlorotic (yellow), cupped and reduced in size, with shortened petioles. Older leaves may take on a red colour before turning brown. Whole plants may wilt and appear flattened before death.

Leaf symptoms alone do not allow for a reliable diagnosis of aster yellows, but flower and fruit symptoms can make field identification possible. Should infection occur at an early stage of flower development, fruit production may be completely aborted, and the achenes may give rise to leaves. Similarly, flowers and fruit will take on an appearance comparable to that of stunted, greatly distorted leaves (see Figure 52).

Infections taking place later in the fruiting process may reduce fruit yield, but flowers will appear normal. As flowers develop over periods of several days or weeks, several symptom stages may be observed in the same field or on the same plant.

The aster yellows phytoplasma has two strains, the eastern and the western form, and can be spread by three types of leafhopper. Only *Macrosteles fascifrons* (the aster leafhopper) is capable of transmitting the eastern strain.

Control/Management

If aster yellows is a recurring problem in your field, monitoring and controlling leafhopper populations is recommended. If pest numbers warrant, insecticide sprays may help to reduce leafhopper populations.

Color Section 3

Photo Courtesy MAFRI

***Figure 45A**. Leaf scorch – note coalescing lesions*

Photo Courtesy MAFRI

***Figure 45B**. Leaf scorch*

Photo Courtesy MAFRI

***Figure 46A**. Common/mycosphaerella leaf spot – note difference in lesion appearance due to cultivars and weather*

Photo Courtesy MAFRI

***Figure 46B**. Common/mycosphaerella leaf spot*

Photo Courtesy MAFRI

***Figure 46C**. Common/mycosphaerella leaf spot*

Photo Courtesy MAFRI

***Figure 47A**. Powdery mildew – note the upward curling leaves*

Photo Courtesy MAFRI

***Figure 47B**. Powdery mildew – field view – note upward curling leaves*

Photo Courtesy MAFRI

***Figure 48**. Anthracnose fruit rot*

Photo Courtesy MAFRI

***Figure 49**. Gray mould on fruit*

Photo Courtesy MAFRI

***Figure 50**. Red stele of strawberry – note stunting and reduction in root mass and health*

Photo Courtesy MAFRI

***Figure 51**. Verticillium wilt – note the brown dried leaves*

Photo Courtesy MAFRI

***Figure 52**. Virus infected plant – note stunting and reduced size in left-hand plant*

Strawberry Insects

Many insects appear on strawberries in various years. Not all insects are pests, causing economically significant damage. It is important to correctly identify pests and determine whether they are occurring in damaging levels, which will require control. Some pests attack multiple plant parts, whereas others attack only specific areas. Careful and diligent scouting for insects and the symptoms of their presence is critical at all stages of crop growth and development. See the following colour image section for pictures of insect pests and damage (Figures 53 to 72).

NOTE: *Portions of this section are adapted from either: 1) a paper authored by Dr. N.J. Holliday, Department of Entomology, University of Manitoba, titled "Integrated Pest Implications for Manitoba Strawberry Growers – 1988" or 2) the "Manitoba Fruit Crop Insect Guide," authored by Brent Elliott, Manitoba Agriculture, Food and Rural Initiatives.*

Insects that attack the foliage

Leafrollers (various species)

Description/Life Cycle

A number of different leaf rollers may appear on strawberries and cause damage to differing degrees (see Figure 53):

- strawberry leafroller (*Amcylis comptana fragariae*)
- garden tortrix (*Ptycholoma peritana*)
- oblique-banded leafroller (*Choristeneura rosaceana*)
- omnivorous leaftier (*Cnephasia longana*)

Damge/Symptoms

Young larvae of the moths feed on either side of the leaf. Often, two adjacent leaflets are tied together or a single leaf is rolled. Damage is usually more common on new plantings late in the growing season (see Figure 54).

Control/Management

Leaf rollers are very susceptible to attack by several parasites, and populations are usually kept at low levels. Insecticide application is usually not necessary. Occasionally, high populations coincide with fruiting and can cause severe damage.

Aphids

Description/Life Cycle

Aphids are small, soft bodied and usually green or yellow (see Figure 55). They seldom cause direct injury, but some transmit virus diseases. Several kinds of aphids feed on the undersides of leaves or stems.

Control/Management

Aphids are not typically a problem in most of the prairie provinces, as natural predators (biological controls) tend to keep populations below economic injury levels. If damaging thresholds are reached, aphids may be controlled by chemical sprays. If sprays are used, it is important to observe the appropriate pre-harvest interval for the chemical used.

Cyclamen mite (Steneotarsonemus pallidus)

Description/Life Cycle

Mites are not considered true insects. This mite is small and scarcely visible to the naked eye. It commonly occurs in strawberries of Manitoba and often causes serious damage and losses to strawberry plantings on a regular basis.

Damage/Symptoms

The cyclamen mite feeds on the young unfolding leaf in the crown of the plant. Damaged leaves are stunted, crinkled and malformed when they emerge (see Figure 56). Later, the mite feeds on blossoms, causing distorted fruit to form.

Control/Management

Use plants free of mites to establish a new planting. Once present, mites are hard to control. High populations can develop during hot dry weather, and study has sown that densities of 45 to 65 mites per leaf can result in a 33 per cent yield reduction.

Maintaining plant vigour and avoiding water stress are important factors in enabling plants to tolerate cyclamen mite populations.

Cyclamen mites are not very mobile, but are often transmitted to new plantings on nursery stock or equipment. Physical field separation and the prevention of accidental transportation of plant debris from infested stands are important control methods.

Biological control is feasible in strawberry plantings, with predators commercially available.

Two-spotted spider mite (Tetranychus urticae)

Description/Life Cycle

The two-spotted spider mite is an injurious pest that feeds by sucking out the contents of individual cells.

Damage/Symptoms

Population densities of one to five mites per leaf result in a mottling of leaves. Research has shown that the mottling changes to general bronzing at densities of 20 mites per leaf. At higher densities, leaves become covered in webbing and dry up. Severely attacked plants lose vigour and die (see Figure 57).

Mites feeding at low densities may reduce fruit production even when there is no visible injury. Research has established that a count of five mites per leaf before July 30 represents an economic threshold for perennial strawberry plantings.

Monitoring

To monitor this pest, examine the undersides of the leaves. The adults are about 0.4 mm (1/65 in.) long and leave telltale signs of webbing. Expect higher mite populations on plants that have undergone some form of stress.

Control/Management

Acaricides work better than general insecticides in most cases; however, where resistance to acaricides is present, insecticides may perform better.

Spider mite predators tend to become established as a strawberry planting matures, provided the natural build-up is not prevented by the use of insecticides.

Leafhoppers (various species in the family Cicadellidae)

Description/Life Cycle

Various species of leafhoppers may be found on different host crops (including chokecherry, saskatoon berry, raspberry and strawberry) and are found in all geographical regions. Although frequently observed in strawberry plantings on the prairies, leafhoppers are not an economic problem in the majority of years.

Leafhoppers are present from late-May through to early October. Leafhoppers are small wedge-shaped insects, 3 to 5 mm (1/8 to 13/64 in.) in length, and their colour varies from white to pale green to yellow to black.

Most have a single generation per year, and many of the species found in Canada do not overwinter here, but migrate in on wind currents from the United States. Some species have many generations per year. They are very active insects and fly or jump when disturbed. Feeding is done on the underside of leaves by piercing the plant tissue and sucking out juices.

Damge/Symptoms

The type of damage often depends on the species causing the damage. Leafhoppers are seldom a cause for concern in strawberry (see Figure 58).

Monitoring

Leafhoppers may be monitored using yellow sticky traps. When leafhoppers are abundant, their presence may be monitored by visually inspecting leaves.

No economic thresholds have been established for leafhoppers. Control measures should only be undertaken on strawberry when numbers are very high (>25/plant). Damage in strawberry plantings generally occurs only in the year of establishment.

Control/Management

Good weed control is essential because weeds can provide cover for the leafhoppers when not on the host plant.

Insects that attack the blossoms or fruit

Tarnished plant bug (Lygus lineolaris)

Description/Life Cycle

The tarnished plant bug is one of the most serious and widespread strawberry pests. They are especially destructive on day-neutral strawberries grown on the prairies.

The insect is small and green in the early nymph stage. Adults are flat, level, have parallel sides for most of their length and are 6 mm (1/4 in.) with mottled brown or brown colorations (see Figure 59).

The adults fly when disturbed. Adults overwinter in plant debris and lay their eggs on the plant stems in the spring. The young hatch and then feed on the developing blossoms and fruit. When fruiting is completed, adult bugs leave.

In most June bearing plantings on the prairies, bugs migrate into fields in the fall or spring and then leave in June or July. Day-neutral strawberry plants may sustain populations continuously because of the different fruiting habit.

The insect forages on a wide variety of flowers that bloom at different times, including alfalfa. Tarnished plant bugs have also been observed feeding on sunflower windbreaks. Cutting off the flower heads at an early stage of their development may discourage this activity.

Damge/Symptoms

Nymphs feed on the blossoms, which subsequently develop into nubbins or deformed fruit. Feeding by nymphs can also result in apical seediness of the fruit. Adult tarnished plant bugs also feed on the developing fruit. This feeding causes "cat faced" berries (see Figure 60).

Tarnished plant bugs can damage as much as 85 per cent of the fruit. Research has shown that 1 nymph per inflorescence resulted in 20 to 30 per cent of the fruit being injured, which reduced the average berry weight by 18 per cent. The economic threshold for treating for tarnished plant bug damage is, on average, less than one nymph per inflorescence.

NOTE:
While the feeding of tarnished plant bug adults may result in "cat facing," a number of other factors may result in similar, if not identical, symptoms. These factors include poor pollination, cold weather during fruit development and nutrient deficiencies. It is critical to correctly determine the cause of misshapen fruit before taking corrective action. Failure to consider alternative causes may result in unnecessary insecticide use and unnecessary costs for growers.

Monitoring

Scout the perimeter of the field first, especially for newly established plantations. Be sure to scout the entire field in subsequent years. Sheltered, mulched or old fields are most at risk.

Using a non-metallic pie plate, tap plants or shake fruit clusters over the plate to collect insects for counting. Survey the field, beginning at pre-bloom and continue until green fruit stage. Proceed through the field in a zigzag fashion, and count the number of nymphs per 100 clusters or samples.

To save on time and effort, use a process of sequential sampling whereby you count the number of infested clusters instead of the number of nymphs. Continue sampling until you have reached a threshold. For detailed sequential sampling instructions and threshold limits, see the website: http://www.gov.on.ca/OMAFRA/english/crops/facts/92-108.htm

It is important to correctly identify the presence of tarnished plant bugs before using chemical sprays.

Control/Management

For control in day-neutral strawberries, use chemicals that have some carryover effect before fruiting. This step can be followed by a spray with a short days-to-harvest interval material applied two to three times per week throughout the fruiting period.

Strawberry bud weevil/Strawberry clipper weevil (Anthonomus signatus)

Description/Life Cycle

This dark, reddish brown weevil is about 3 mm (1/10 in.) long with a head that has a slender curved snout about half as long as the body (see Figure 61).

The adult beetles leave their winter quarters in fence rows and woodlands about the time the first strawberry blooms appear. Eggs are deposited in the blossom as it opens or in buds that are nearly matured. The adult then cuts the stem of the bud, and it falls to the ground or hangs by a thread (see Figure 62). In one week, the eggs hatch into white, legless grubs. Larva develop inside the bud and reach maturity in three to four weeks.

The new generation of adults appear in early summer and are active in late June or July. No damage occurs at that time. After feeding on the pollen of various flowers for a short time, the pests seek hibernating sites until the next spring. There is one generation each year.

Damge/Symptoms

This insect is known as "the strawberry clipper" or simply "clipper" because of its habit of clipping buds (see Figure 62).

Monitoring

Early blooming cultivars are more prone to "clipper" damage. Monitor fields frequently in May when flower buds begin to develop. A rough economic injury level appears to be 13 to 20 clipped buds per metre (yard) of row. Control measures should occur before this level is reached. Injury is most likely to occur where strawberries are grown adjacent to woodlands or other suitable hibernating areas.

To scout the clipper weevil, sample 0.6 row metres (2 row feet) of strawberries in 5 localities within the field. Repeat twice a week from the pre-bloom stage onward.

Control/Management

Cultural control includes minimizing the amount of trash in and around fields during mid to late summer and separating new plantings from old crops with high clipper populations. Vigorous tillage of the old beds immediately following the final harvest will minimize movement of the clipper to the new plantation. Clippers are vulnerable to tillage at this time because they are in the immobile pupae stage in the soil.

Thrips (Frankliniella tritici and potentially other species)

Description/Life Cycle

Thrips have been relatively minor pests in Western Canada until recently. Damage caused by thrips has been reported in Alberta, Manitoba, Ontario and New Brunswick. They are also common pests in central and northeastern parts of the United States and are a serious pest in Australia.

Thrips are tiny (1.3 mm or 3/64 in. in length) cigar-shaped insects. Adults are brown to yellow, have fringed wings and are weak fliers. Adult females lay eggs directly in plant tissues. Immature thrips (nymphs) are wingless, fast moving and yellow (see Figure 63). Adults and nymphs prefer to hide in protected places.

Thrips are not known to overwinter in large numbers in Canada. The insects are thought to migrate in each year on southerly wind currents. Within a growing season, they can complete several generations in a short period.

Damge/Symptoms

While thrips are a common sight on strawberries, significant injury from them is unusual. Thrips damage is caused by the rasping-sucking action of their mouthparts. They begin feeding on seeds immediately after the buds open.

The rasped areas of the berry under the cap tend to crack and split as the fruit grows. Early damage to berries results in fruit being scarred and discoloured just beneath the calyx. Mature berries tend to be seedy, smaller, cracked and brownish and have a rubbery consistency. Bronzing, as the damage is called, is caused by feeding damage just under the calyx when the fruit is from 10 to 20 mm (13/32 to 25/32 in.) in diameter (see Figure 64).

Heavy infestations can almost completely destroy the buds and flowers before the fruits have had a chance to develop. In Australia, thrips have caused damage similar to that caused by tarnished plant bug. This "cat facing" has not been observed in North America, and the species that causes the damage in Australia does not occur in North America.

Monitoring

Collect 10 flower buds in a sealable plastic bag. Place the bag on the hood of a vehicle so that the heat will kill the thrips, making them easier to count. Repeat the process in various locations to get an indication of the population of thrips across the field. Count the number of thrips per flower to determine whether the economic threshold has been reached. Sticky traps may also be used to monitor this insect.

Treatment for thrips is not recommended unless populations exceed 10 per blossom. When berries reach a size of 10 mm (13/32 in.), examine 50 randomly selected fruit. If, on average, there are more than 0.5 thrips per fruit (or 25 thrips per 50 fruit), control measures are recommended. Although thrips can cause economic damage in strawberries, the decision to control them should be based on the economic threshold as flower thrips also feed on spider mite eggs.

Control/Management

Control of thrips is typically accomplished using chemical sprays. Spraying should only be done if economic thresholds are reached during regular scouting.

Insects that attack the crown or roots

Strawberry root weevil (Otiorhynchus ovatus)

Description/Life Cycle

A number of weevil species attack strawberry plants. In the immature stage, these weevils are legless, live in the soil and feed on the fibrous roots of strawberries or tunnel into the crown. The adult weevils are brownish or blackish and 5 to 10 mm (13/64 to 13/32 in.) long (see Figure 65).

Larva or adults overwinter in trash.

Damge/Symptoms

Adults feed at night on the edges of leaves, causing the leaves to appear ragged or notched. In contrast, caterpillar feeding damage tends to consist of extensive, round-shaped holes (see Figure 66).

Populations of strawberry root weevils tend to increase as the planting ages and can severely stunt or kill plants.

Monitoring

Strawberry root weevils are unable to fly, so damage is restricted to small areas. Watch for leaf damage, and examine the crowns of weak plants for evidence of root weevil injury. Monitoring on a continuing basis should not be necessary.

Control/Management

Strawberry root weevils may be controlled with insecticides. Growers can also use cultural controls, such as crop rotation and isolating fields from wild plants that harbour weevils. Tillage is not very effective in destroying weevils.

Wireworms

Damge/Symptoms

Wireworms occasionally cause serious injury to new plantings. Wireworms crush the root tissue, resulting in poor plant growth. Symptoms of damage resemble those of other factors that cause stress. Damage is usually apparent as weakened or missing plants in a row or in whole patches across the field.

Monitoring

Inspect fields carefully to determine wireworm populations before transplanting strawberries. A few wireworms per square metre (square yard) can do serious damage to strawberry plants.

Control/Management

Wireworms are best controlled in the crop rotation phase when planting to a cereal crop.

Insects that attack the whole plant

Cutworms *(Amphipoea interoceancia and other species)*

Description/Life Cycle

A number of species of these voracious caterpillars may feed on different plant parts at any time during the growing season. Predominant species will vary depending on location in the prairie region. The stout caterpillars are nearly 25 to 37 mm (1 to 1.5 in.) long and are striped, mottled or dingy grey (see Figure 67). They feed at night and are seldom observed in the fields. During the day, they burrow into the soil or hide beneath plant debris. Unlike slugs, they do not leave slime trails.

Some cutworms that attack strawberry plants overwinter as partially grown caterpillars in the field, and they become active early in the spring. As they reach full growth, they pupate in the soil. Brownish or greyish moths emerge and are active only at night (see Figure 67). Some species overwinter in the egg stage.

The strawberry cutworm *Amphipoea interoceancia* was identified in the mid-1970's. Eggs of this species are laid on dead strawberry leaves in August and hatch in early May. Young larvae feed on leaf stalks. Later, they bore into the crown and kill the plants.

Adults of this species seem to have a short flight range. Females lay eggs in an established field, where the larvae probably feed. Females seldom leave the field unless the crop can no longer serve as pasture.

Damge/Symptoms

Young plants are occasionally cut off at the soil surface by strawberry cutworms (see Figure 68). Cutworms may also feed on the leaves of older plants, but cause insignificant damage unless they are very abundant.

Damage may also result when cutworms feed on ripe fruit, making large holes in the berries. These holes are larger than those made by leaf rollers. Each cutworm feeds on a number of berries in a localized area.

In some areas, such as Manitoba, much of the damage caused by cutworms is clipping of the plants, rather than feeding on the berries. This type of damage is due to the timing of the larval life cycle in relation to the timing of fruiting.

Plants are first attacked in the second year of growth. By the fifth year, the entire planting may be lost. Second-year stands may show patchy infestations, which become more severe as the stands age. This general decline in vigour is often mistaken as winter injury (see Figure 68).

Monitoring

Economic thresholds for cutworms in strawberries have not been established. Cutworms that attack the crowns or several fruiting stems are much more damaging than those that eat leaves. The economic threshold for leaf feeding species will be much higher than those affecting fruiting structures or plant survival.

Control/Management

The fact that cutworms do not tend to leave a field and have a limited flight range makes them easier to control because an insecticide application will kill the population, and others will not move into the area. For chemical control, apply only those compounds specifically recommended for cutworms.

Because many species overwinter in fields as eggs or partly grown larvae, tillage after the final harvest can help control cutworm populations.

Other insect pests

Many insects occur on strawberry plants and cause aesthetic or cosmetic damage to plant parts and/or fruit. Control is typically not required, but recognition of these insects is important.

Leatherjackets

Description/Life Cycle

Leatherjackets are the soil-dwelling, larval stage of the crane fly. The insects have a wide host range, including strawberries. Leatherjackets occasionally occur in fairly high numbers in wetter areas of eastern Saskatchewan.

Leatherjackets are fat, soft-bodied, brown to greyish black, legless creatures, up to 4 cm (1.6 in.) long. They do not have a distinct head.

Damge/Symptoms

They feed on the roots and occasionally the stems of plants, causing gradual weakening and death. This damage is typically observed in the spring, but may occur at other times.

Control/Management

No effort is typically made to control these pests.

Spittlebugs *(Philaenus spumarius and other species)*

Description/Life Cycle

Spittlebugs are seldom a serious problem in the Canadian prairies, but are found throughout North America and are pests of strawberry plantings in areas of high relative humidity such as the Pacific Northwest. In Manitoba, in years where there is above average precipitation, spittlebugs can be quite prevalent. Spittlebugs feed on a variety of hosts including strawberry, clovers, grasses, weeds and some ornamentals.

Adult spittlebugs are 5 to 7 mm (13/64 to 9/32 in.) in length and are dull brown. Nymphs vary from white to pale green and have dark eyes and distinct legs (see Figure 69). Spittlebugs overwinter as eggs on the lower leaves and stems of host plants and in the stubble of strawberry plantings. The egg hatch coincides with appearance of blossoms.

The nymphs are often found on and between clusters of flower buds and within the crown. Nymphs mature in late June and emerge from the spittle as winged adults. There is one generation per year.

Damge/Symptoms

Nymphs feed within a frothy mass of spittle (hence the common name) by piercing plant tissue and sucking plant juices (see Figure 70).

In the Canadian prairies, spittlebugs seldom cause economic damage. Most often, spittlebugs are a nuisance, as pickers dislike the appearance of the spittle. During wet summers or in fields under heavy irrigation, the numbers of spittlebugs may be high enough to weaken plants and distort leaves and berries.

Monitoring

Fields are easily monitored for the froth or spittle created by the nymphs while feeding. During hot dry weather, nymphs will be lower on the plant making them more difficult to locate.

As spittlebugs seldom cause economic damage, there is no established economic threshold. A threshold based on the aesthetic appearance of the plants to pickers is considered one froth mass per square foot.

Control/Management

Growers should strongly consider the effect of insecticides on predators and parasites before controlling what is not an economic problem. Insect populations are higher in weedy fields, and proper weed control can keep the numbers down.

Slugs *(Deroceras laeve and other species)*

Description/Life Cycle

Slugs have damaged strawberries in Manitoba, but do not appear to be active in other areas of the prairies. Although the loss of fruit from slug feeding is usually not significant, customers are repelled by the presence of slugs on the fruit they are picking or by the slime they leave behind.

The native marsh slug (*Deroceras laeve*) overwinters as an adult in trash and leaf litter in hedgerows and windbreaks. Most eggs are laid in June and July. By fall the slugs are full grown and about 15 mm (19/32 in.) long.

For most of the year, slugs feed on fungi and decaying vegetation in the trash. However, slugs will feed on strawberries when they are present and particularly if field conditions are wet (see Figure 71).

Damge/Symptoms

Slug populations can build up and cause severe losses over the life of the strawberry planting. Some fruit loss may occur from slug feeding. A slime trail will be evident.

Monitoring

Slugs are difficult to monitor because they are usually in the soil and inactive. To estimate populations, search 0.1 m^2 (1 sq ft.) areas of straw mulch and trash, digging down to the compacted soil. Watch for the presence of slug eggs or slugs. Badly infested fields may contain up to 50 slugs/m^2 (10/sq ft.). These populations will only pose a severe problem if field conditions are wet at harvest.

Control/Management

Prevention of population build-up is a better objective than treatment of a heavy infestation.

When damage occurs early in the fruiting season, apply chemical controls or till headlands and inter-row areas. The use of slug baits has met with some success. Banding sprays over the rows during the hours of slug activity can also be effective. Cultural control by slug habitat management is probably the most effective measure. Limiting excessive straw use and adopting vigorous tilling at renovation will also help.

Slugs seldom move far by themselves, but are often transported with tillage equipment or soil. Precautions should be taken to prevent subsequent introduction in this way.

Other Strawberry Pests

Nematode problems in strawberry production

Nematodes are small worm-like organisms that can be found in virtually all environments around the world. A number of nematodes are plant parasitic and can attack a number of different plants, including strawberry. While many nematodes can cause damage on their own, they can also wound or stress otherwise healthy plants, enabling entry of other pathogens, resulting in decreased crop production or the death of entire plants.

On their own, nematodes can typically only move a metre, at most, in the soil in a season. Movement of soil by equipment, wind, erosion, or livestock can transport nematodes over a much wider range.

For significant damage to occur, plant parasitic nematodes need to reach a certain population (threshold) level, which will differ with the species. Populations above these levels will require management decisions to be made to reduce economic damage.

If you suspect a nematode problem, take samples of soil and roots to confirm that nematode damage is occurring. Collect samples within the root zone of the strawberry plants. Nematode soil tests need to be done at a lab and are best performed during August or September. A number of diagnostic clinics perform this service for a fee. Please contact your provincial plant pathologist or crop specialist for information on laboratories that can conduct nematode tests.

On the prairies, nematode problems on strawberries do not appear to be very common, though some species (notably the root lesion nematode) are being recognized as emerging problems in other crops.

Root lesion nematodes *(Pratylenchus spp.)*

While not reported specifically on strawberries grown on the Canadian prairies, root lesion nematodes have been found living in prairie soils. Of the species associated with strawberry, *Pratylenchus penetrans* is considered the most pathogenic. It is associated with a wide range of hosts, most notably potato and corn, but can also be common in strawberry fields.

The nematode enters the root, moving through and between the cells of the plant. The entry points of the plant appear as tiny dead areas on the plant roots, appearing light brown to black. Observed above ground, plants appear stunted, produce few runner plants, and have shortened and more upright petioles.

In addition to the direct impact of the nematode are the added effects of interactions with other fungi, initiating other root diseases, such as black root rot.

Other nematodes

As of 2004, very little concern over damage attributed to other nematodes has been reported.

Bird damage

Though generally a relatively minor problem across the prairies, damage attributed to birds has the potential to cause significant reductions in fruit quality, both through direct damage and predisposing of fruit to invasion by fruit rotting fungi (see Figure 72). If losses due to bird-damaged ripening fruit are resulting in high economic losses, management may be necessary. Managing bird damage can be difficult, as birds can learn to adjust to some tactics.

Protective netting can be an effective barrier to most bird species, if severe damage has been a problem. Placing netting on poles over the plants as the fruit ripens will reduce the damage. Be sure to position the netting high enough over the plants, so that access to the fruit by staff and customers is not restricted.

Noisemaking equipment can be used to frighten birds away from strawberry fields. A variety of noisemakers are commercially available, including propane cannons or exploders ("bird bangers"), electronic alarm or distress calls. If noisemakers are used, they are best applied as soon as birds begin arriving in the field and become familiar with the location.

Visual repellents can work on some bird species. These may include balloons meant to appear as predators, (e.g. large-eye balloons), metre-long (yard-long) strips of mylar attached to stakes and placed throughout the strawberry field that blow and reflect sunlight. In both of these cases, the repellents should be moved often. Despite these precautions, any bird species frightened away initially may return after a short period.

Before deciding whether to manage bird damage, record when and where damage problems are most prevalent during the season, as this information will help in preparing your management strategy in advance.

Color Section 4

Photo Courtesy C.C. Peters

***Figure 53A**. Strawberry leafroller*

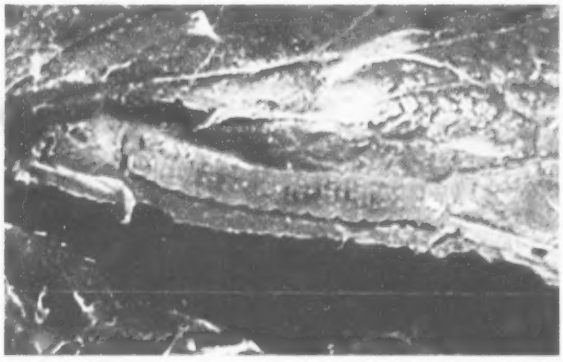


Photo Courtesy C.C. Peters

***Figure 53B**. Garden tortrix larva*

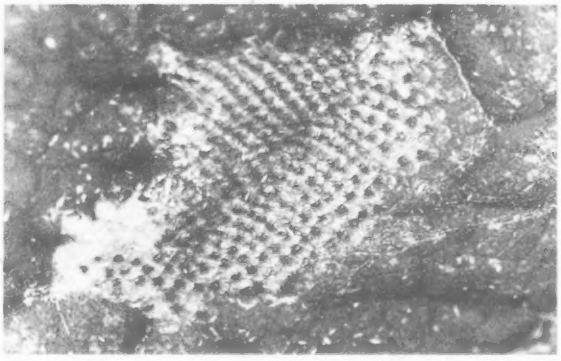


Photo Courtesy S.M. Fitzpatrick and J.T. Troubridge

***Figure 53C**. Oblique-banded leafroller egg mass*

Photo Courtesy MAFRI

***Figure 53D**. Leafroller larva in strawberry leaf*

Photo Courtesy MAFRI

***Figure 54**. Leafroller damage to strawberry*

Photo Courtesy MAFRI

***Figure 55A**. Aphids*

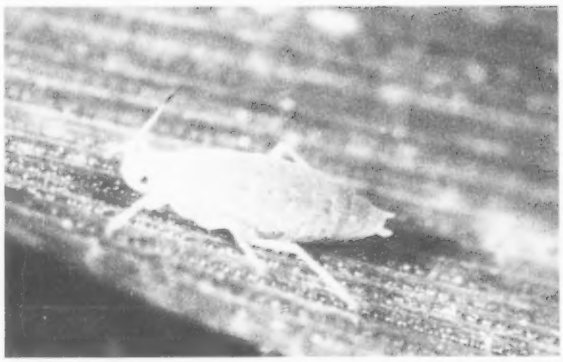


Photo Courtesy MAFRI

***Figure 55B**. Aphid*

Photo Courtesy MAFRI

***Figure 56**. Cyclamen mite damage on strawberry*

Photo Courtesy Marion Herbut, ARC

***Figure 57A**. Two-spotted spider mites*

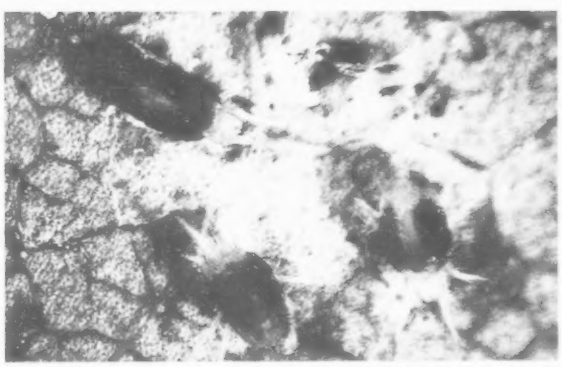


Photo Courtesy Marion Herbut, ARC

***Figure 57B**. Two-spotted spider mites – note spots*

Photo Courtesy OMAF

***Figure 58**. Leafhopper damage on strawberry*

Photo Courtesy MAFRI

***Figure 59A**. Tarnished plant bug – nymph*

Photo Courtesy Marion Herbut, ARC

***Figure 59B**. Tarnished plant bug – adult – note distinctive triangular marking*

Photo Courtesy MAFRI

***Figure 60**. Tarnished plant bug damage – cat facing*

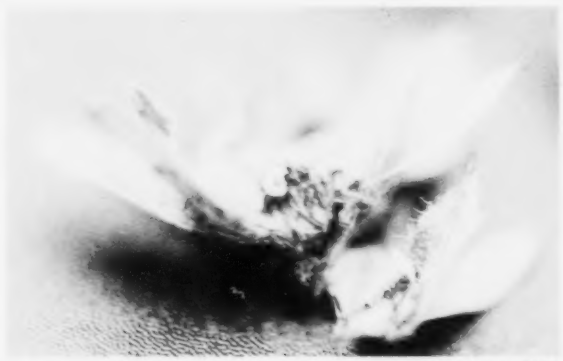


Photo Courtesy MAFRI

***Figure 61A**. Strawberry bud/clipper weevil – larva*

Photo Courtesy NYSAES Cornell

***Figure 61B**. Strawberry bud/clipper weevil – adult*

Photo Courtesy MAFRI

***Figure 62**. Strawberry bud/clipper weevil damage in strawberry*

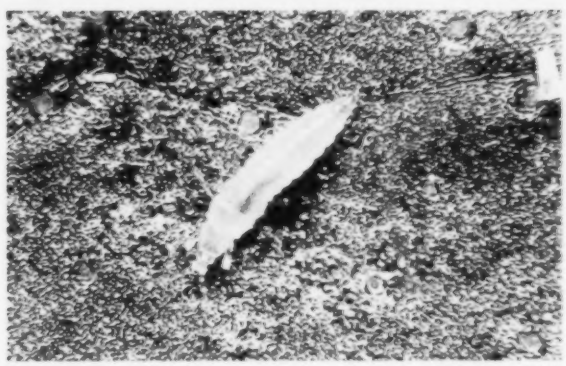


Photo courtesy MAFRI

***Figure 63A**. Western flower thrips (WFT) – nymph*

Photo courtesy Kelvin Lynch

***Figure 63B**. Thrips – adult*

Photo courtesy Kelvin Lynch

***Figure 64A**. Typical thrips damage – bronzing*

Photo courtesy Kelvin Lynch

***Figure 64B**. Severe thrips damage – severe bronzing, cracking and bract necrosis*

Photo Courtesy MAFRI

***Figure 65A**. Strawberry root weevil adults and larvae on soil surface*

Photo Courtesy MAFRI

***Figure 65B**. Strawberry root weevil – adult*

Photo Courtesy MAFRI

***Figure 66**. Strawberry root weevil damage to strawberry*

Photo Courtesy MAFRI

***Figure 67A**. Mature cutworm – larva*

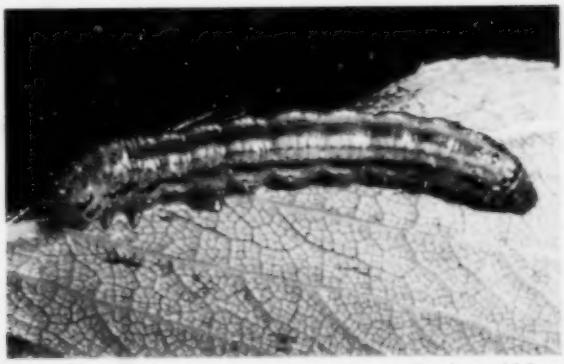


Photo Courtesy C.C. Peters

***Figure 67B**. Strawberry cutworm – larva*

Photo Courtesy MAFRI

***Figure 67C**. Strawberry cutworm – adult*

Photo Courtesy MAFRI

***Figure 68A**. Early signs of strawberry cutworm damage – clipped stems*

Photo Courtesy MAFRI

***Figure 68B**. Strawberry cutworm damage – field scale*

Photo Courtesy NYSAES-Cornell

***Figure 69A**. Spittle bug – nymph*

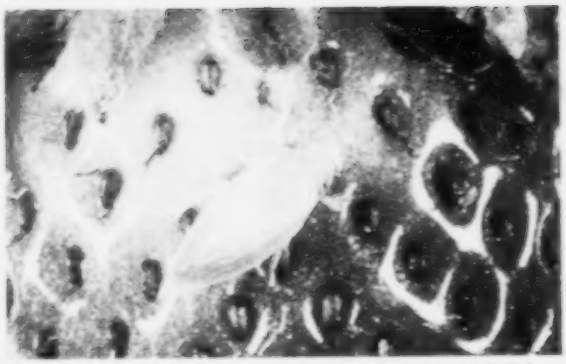


Photo Courtesy NYSAES Cornell

***Figure 69B**. Spittle bug – nymph*

Photo Courtesy NYSAES Cornell

***Figure 69C**. Spittle bug – adult*

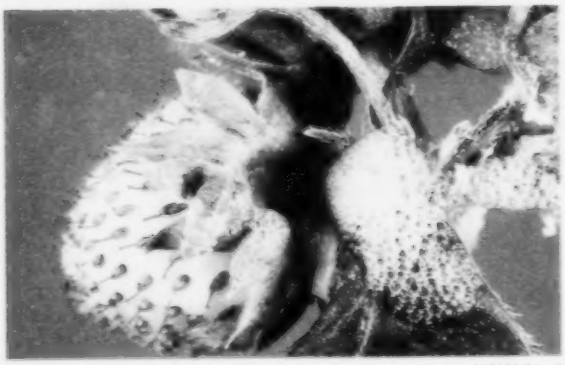


Photo Courtesy NYSAES Cornell

***Figure 70**. Spittle bug – frothy mass*

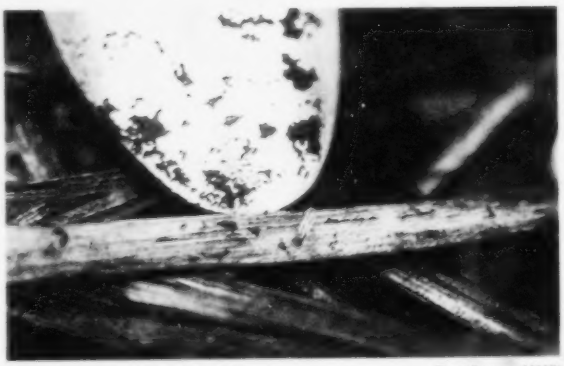


Photo Courtesy MAFRI

***Figure 71A**. Slugs on trash*

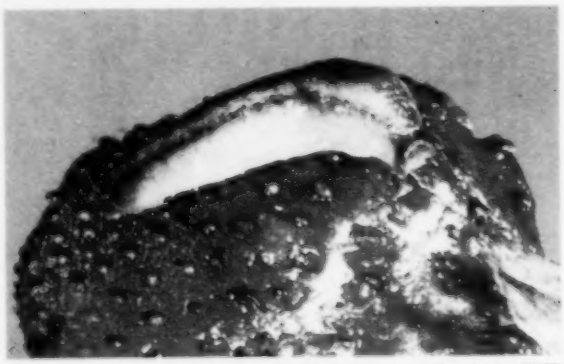


Photo Courtesy MAFRI

***Figure 71B**. Slug on strawberry fruit*

Photo Courtesy MAFRI

***Figure 72**. Bird-damaged strawberry fruit*

Weed Management

An effective weed control program combines initial identification of the weeds with appropriate cultural and chemical control procedures. Consult your provincial weed guide for recommended herbicides, rates of application and spraying procedures.

Precaution – phytotoxicity

Note: Portions of this section have been adapted from the "Guide to Chemical Control for Strawberry Production in Atlantic Canada" 1989; Publication 1012."

Herbicides must be applied at the recommended rates to avoid strawberry injury. Cultivars vary in their sensitivity to herbicides at certain stages of the plant growth cycle. The application of a trial strip of the herbicide in the field before overall treatment is recommended when specific cultivar recommendations are not available.

A chance of phytotoxicity (plant poisoning) attributable to excessive rates or the stage of plant growth is much greater with herbicides than with most other pesticides. Crop injury from the use of herbicides is not uncommon, particularly on light soils.

Post-emergent application injury can result from use of a high rate on light soils, improper timing of sprays, improperly calibrated sprayers, sensitive cultivars and weak plants growing under unfavourable conditions. Injury can take the form of temporary chlorosis or yellow "haloing" of margins around the leaf edge. This stage is followed by complete chlorosis and finally, the death of the plant.

Newly planted and actively runnering strawberries are especially sensitive to herbicides. Crop tolerance increases in late summer and fall.

Light soils (sandy soils) require lower rates than heavy soils for comparable levels of weed control. Strawberries growing on soils low in organic matter are especially prone to herbicide injury.

Lower rates of herbicides should be used on fields containing less than 2 per cent organic matter. Do not exceed the maximum recommended annual application rates or overlap areas during application. The use of a flat fan type nozzle is recommended.

Preparing the land

To ensure optimum weed control throughout the entire life of the strawberry field, you need to establish the crop in soil that is as weed free as possible.

In fields with perennial weeds such as quackgrass and thistle, do not cultivate in the fall before a fallow year. Short-term cultivation tends to propagate rather than control these weeds. Chemical control may be an option for late summer-fall use. In the spring, till at a shallow depth to control annual weeds. Allow perennial weeds to recover and apply herbicides as recommended.

Applying a registered pre-plant herbicide in the spring will reduce labour requirements for weed control in the first year.

On newly-planted strawberries

When the preparation for a new strawberry field includes recommended summer fallow practices and the use of a pre-plant herbicide, only the few weed seeds that germinate should be a problem after transplanting. It is important to realize that the herbicide treatments recommended in the summer after transplanting will not control perennial weeds that grow from underground root structures. Most weeds growing from seed can be controlled if a recommended herbicide is used.

After transplanting

Cultivation will be necessary to control weeds until plants are established. Once plants are well set, herbicides can be applied two ways: as an overall spray, or as a band applied over the row combined with cultivation between the rows. The latter procedure minimizes the cost of herbicide application.

Four to six weeks after transplanting

Several excellent herbicides can be applied after mother plants are well established. At this stage, care must be taken with certain pre-emergent chemicals to ensure full rooting of the mother plant and daughter plants.

Several post-emergent herbicides can also be effective when applied at the correct growth stage of weed seedlings.

In established beds

Applying pre-emergent herbicides in the fall before mulching will give effective control of weeds germinating in the spring. Perennial weeds should be controlled with spot application of herbicides. Registered post-emergent herbicides for broadleaf and grass control can be applied in the bearing year before harvest, providing the "days-to-harvest" intervals are observed.

Several pre-emergent herbicides can be applied after renovation to control germinating weeds up to strawberry dormancy. However, care must be taken to ensure the planting is strong enough to withstand the potential herbicide injury.

Resources

Provincial grower association contact information

Alberta

Alberta Farm Fresh Producers Association
www.albertafarmfresh.com

Box 56
Kelsey, AB T0B 2K0
Toll-free: 1-800-661-2642

Saskatchewan

Saskatchewan Fruit Growers Association
www.saskfruit.com

Box 177
Langenburg, SK S0A 2A0
Tel: (306) 743-5333 Fax: (306) 743-5033

Manitoba

Prairie Fruit Growers Association
www.pfga.com

Box 2430
Altona, MB R0G 0B0
Tel/Fax: (204) 324-5058

Provincial government resources contact information

Alberta Agriculture, Food and Rural Development

Alberta Ag-Info Centre
Postal Bag 600
4705 - 49 Avenue
Stettler, AB T0C 2L0
Toll-free: 1-866-882-7677
Tel: (403) 742-7901 Fax: (403) 742-7527

Provincial Fruit Industry Development Specialist
Crop Diversification Centre South
SS#4
Brooks, AB T1R 1E6
Tel: (403) 362-1309

Duke (e-mail)
duke@gov.ab.ca

AAFRD Ropin' the Web
www.agric.gov.ab.ca

Saskatchewan Agriculture, Food and Rural Revitalization

Agriculture Knowledge Centre
45 Thatcher Road East
Moose Jaw, SK S6J 1L8
Toll-free: 1-866-457-2377
Fax: (306) 694-2377

Provincial Fruit Development Specialist
Room 125
3085 Albert Street
Regina, SK S4S 0B1
Tel: (306) 787-4666 Fax: (306) 787-0428

SAFRR Website
www.agr.gov.sk.ca

Manitoba Agriculture, Food and Rural Initiatives

Fruit Crop Specialist/Entomologist/Plant Pathologist/Weed Specialist
Soils and Crops Branch, Manitoba Agriculture, Food and Rural Initiatives
Box 1149
Carman, MB R0G 0J0
Tel: (204) 745-5660 Fax: (204) 745-5690

MAFRI Website
www.gov.mb.ca/agriculture

Pesticide information

Alberta

Alberta Ag-Info Centre
Toll-free: 1-866-882-7677

Saskatchewan

Contact provincial specialist for recommendations

Manitoba

MAFRI Fruit Guide – Fruit Crop Protection Section (updated every 2 years)

Pest Management Regulatory Agency

Toll-free contact 1-800-267-6315
Searchable Electronic Label Database
www.eddenet.pmra-arla.gc.ca/4.0/4.0.asp

Plant health diagnostic laboratory facilities

Alberta

20/20 Seed Labs
201, 509 - 11 Avenue
Nisku, AB T9E 7N5
Toll-free: 1-877-420-2099
Tel: (780) 955-3435 Fax: (780) 955-3428

BioVision Seed Labs
7225B Roper Road
Edmonton, AB T6B 3J4
Toll-free: 1-800-952-5407
Tel: (780) 436-8822 Fax: (780) 437-6875
E-mail: biovision@biovision.ca

Saskatchewan

Crop Protection Laboratory
Mailing Address:
Room 125
3085 Albert Street
Regina, SK S4S 0B1
E-mail: gholzgang@agr.gov.sk.ca

In Person:
346 McDonald Street
Regina, SK S4N 6P6
Tel: (306) 787-8130 Fax: (306) 787-8803

Manitoba

Crop Diagnostic Centre
Soils and Crops Branch, Manitoba Agriculture, Food and Rural Initiatives
Agricultural Services Complex
545 University Crescent
Winnipeg, MB R3T 5S6
Tel: (204) 945-7707

Soil testing/analysis laboratories

Alberta

EnviroTest Laboratories

9936 - 67 Avenue
Edmonton, AB T6E 0P5
Tel: (780) 413-5227
Toll-free: 1-800-668-9878

Bay 2, 1313 - 44 Avenue N.E.
Calgary, AB T2E 6L5
Tel: (403) 291-9897
Toll-free: 1-800-668-9878

103, 10919 - 96 Avenue
Grand Prairie, AB T8V 3J4
Tel: (780) 539-5196
Toll-free: 1-800-668-9878

Bay 1, 235 MacDonald Crescent
Fort McMurray, AB T9H 4B5
Tel: (780) 791-1524
Toll-free: 1-800-668-9878

Norwest Labs

7217 Roper Road
Edmonton, AB T6B 3J4
Tel: (780) 438-5522
Toll-free: 1-800-661-7645

#9, 2712 - 37 Avenue N.E.
Calgary, AB T1Y 5L3
Tel: (403) 291-2022
Toll-free: 1-800-661-1645

4605 - 12 Street N.E.
Calgary, AB T2E 4R3
Tel: (403) 291-3024
Toll-free: 1-800-331-8266

3131 - 1 Avenue South
Lethbridge, AB T1J 4H1
Tel: (403) 329-9266
Toll-free: 1-800-773-3962

11301 - 96 Avenue
Grand Prairie, AB T8V 5M3
Tel: (780) 532-8709

Saskatchewan

EnviroTest Laboratories

819 - 58 Street East
Saskatoon, SK S7K 6X5
Tel: (306) 668-8370
Toll-free: 1-800-667-7645

Manitoba

EnviroTest Laboratories

745 Logan Avenue
Winnipeg, MB R3E 3L5
Tel: (204) 945-3705
Toll-free: 1-800-607-7555

Norwest Labs

1357 Dugald Road
Winnipeg, MB R2J 0H3
Tel: (204) 982-8630
Toll-free: 1-800-483-3448

Other soil test laboratories

Agvise Laboratories

P.O. Box 510
Northwood, ND 58267
Tel: (701) 587-6010 Fax: (701) 587-6013

P.O. Box 187
Benson, MN 56215
Tel: (320) 843-4109 Fax: (320) 843-2074

A & L Canada Laboratories Inc.

2136 Jet Stream Road
London, ON N5V 3P5
Tel: (519) 457-2575 Fax: (519) 457-2664
E-mail: aginfo@alcanada.com

Midwest Laboratories Canada

#8, 4001B - 19 Street N.E.
Calgary, AB T2E 6X8
Tel: (403) 250-3317 Fax: (403) 250-5249

Western Ag Labs

#3, 411 Downey Road
Saskatoon, SK S7N 4L8
Tel: (306) 978-0373

Water analysis and interpretation

Alberta

EnviroTest Laboratories

9936 - 67 Avenue
Edmonton, AB T6E 0P5
Tel: (780) 413-5227
Toll-free: 1-800-668-9878

Bay 2, 1313 - 44 Avenue N.E.
Calgary, AB T2E 6L5
Tel: (403) 291-9897
Toll-free: 1-800-668-9878

103, 10919 - 96 Avenue
Grand Prairie, AB T8V 3J4
Tel: (780) 539-5196
Toll-free: 1-800-668-9878

Bay 1, 235 MacDonald Crescent
Fort McMurray, AB T9H 4B5
Tel: (780) 791-1524
Toll-free: 1-800-668-9878

Norwest Labs

7217 Roper Road
Edmonton, AB T6B 3J4
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#9, 2712 - 37 Avenue N.E.
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Tel: (403) 291-2022
Toll-free: 1-800-661-1645

4605 - 12 Street N.E.
Calgary, AB T2E 4R3
Tel: (403) 291-3024
Toll-free: 1-800-331-8266

3131 - 1 Avenue South
Lethbridge, AB T1J 4H1
Tel: (403) 329-9266
Toll-free: 1-800-773-3962

11301 - 96 Avenue
Grand Prairie, AB T8V 5M3
Tel: (780) 532-8709

Saskatchewan

EnviroTest Laboratories

Agriculture Services
819 - 58 Street East
Saskatoon, SK S7K 6X5
Tel: (306) 668-8370 Fax: (306) 668-8383
Toll-free: 1-800-667-7645

Irrigation Development Section
Crop Development Branch, SAFRR
Box 609
Outlook, SK S0L 2N0
Tel: (306) 867-5528
E-mail: gweiterman@agr.gov.sk.ca

Manitoba

EnviroTest Laboratories

745 Logan Avenue
Winnipeg, MB R3E 3L5
Tel: (204) 945-3705
Toll-free: 1-800-607-7555

Other strawberry information

Strawberry Production Guide for the Northwest, Midwest, and Eastern Canada – Northeast Regional Agricultural Engineering Service (NRAES)
Cooperative Extension
152 Riley-Robb Hall
Ithaca, NY 14853-5701

Growing Strawberries in Ontario. (2000)
Ontario Ministry of Agriculture and Food
$20.00 (Ordering information available on-line)

Berry Production Guide for Commercial Growers (2002/2003) – British Columbia Ministry of Agriculture, Food and Fisheries
$30.00 (Cheques payable to LMHIA)
Lower Mainland Horticulture Improvement Association
c/o 1767 Angus Campbell Road
Abbotsford, BC V3G 2M3
Tel: (604) 556-3001 Fax: (604) 556-3030

Compendium of Strawberry Diseases
American Phytopathological Society – APS Press
www.shopapspress.com
APS PRESS Customer Service
3340 Pilot Knob Road
Saint Paul, MN 55121-2097 USA
Tel: (651) 454-7250
Toll-free (USA & most of Canada): 1-800-328-7560

Integrated Pest Management for Strawberries
University of California, Statewide Integrated Pest Management Project, Division of Agriculture and Natural Resources
Publication # 3351

AAFRD Ropin' the Web

- *Strawberry Profit$*
- AgVentures: *Commercial Strawberry/Raspberry Industry*

Manitoba Agriculture, Food and Rural Initiatives, www.gov.mb.ca/agriculture

- *Fruit Guide* (available for order online or by phone, Soils and Crops Branch 204-745-5660) $30.00 (S&H included) (Make cheques payable to Prairie Fruit Growers Association)
- *Fruit Crop Insect Guide* (Order online or by phone, see above; online version also available) $12.00 (Make cheques payable to Prairie Fruit Growers Association)
- *Strawberry U-pick Cost-of-Production Guide* (Order online or by phone, see above; online version also available)
- *Soil Fertility Guide* (Order online or by phone; online version also available)

Manitoba Agriculture, Food and Rural Initiatives,
Soils and Crops Branch
Box 1149
Carman, MB R0G 0J0
Tel: (204) 745-5662 Fax: (204) 745-5690

Other resource materials

B.C. Trickle Irrigation Manual
$40.00 + GST, S&H

Irrigation Association of British Columbia
2330 Woodstock Drive
Abbotsford, BC V3G 2E5
Tel/Fax: (604) 859-8222

OFFS Guidelines for Fresh Fruit and Vegetables Manual
Available by contacting the Canadian Horticultural Council (www.hortcouncil.ca) or your provincial association

Appendix

Feel method for estimating soil water available for crop use

Soils can vary greatly in texture from being very fine (clay) to very coarse (sand) within a crop root zone. Because soil texture can change quite quickly, so can the amount of water the soil is able to hold.

Texture	Available Moisture
Loamy sand	8 - 12 mm/0.1 m (0.9 - 1.4 in./ft.)
Sand loam	10 - 15 mm/0.l m (1.2 - 1.8 in./ft.)
Loam	14 - 18 mm/0.l m (1.7 - 2.1 in./ft.)
Sand clay loam, clay loam, clay	15 - 20 mm/0.1 m (1.8 - 2.4 in./ft.)
Silty clay loam, silt loam	16 - 22 mm/0.l m (1.9 - 2.6 in./ft.)

It is important to know and to be able to calculate the amount of water present in the soil root zone in order to understand the amount of water available for crop use. The allowable depletion level is the amount of soil water that can safely be removed from the root zone by a crop before an irrigation is required. For most crops, the allowable depletion level has been determined to be 50 per cent.

The simplest way to determine soil water content is by the "feel" method. By feeling, squeezing and observing a handful of soil, the amount of water present in the soil can determined. The following chart outlines the various characteristics of soil based on different contents of water.

		Feel or appearance of soils*		
	Per cent of available water remaining	**Moderately coarse texture**	**Medium texture**	**Moderately fine texture**
Do not irrigate	At field capacity 100	Upon squeezing no free water appears on soil, but wet outline of ball is left on hand.	Same as sandy-loam.	Same as sandy-loam.
	75 to field capacity	Forms a weak ball, breaks easily,will not slide.	Forms a ball and is very pliable, slicks readily if relatively high in clay.	Easily ribbons out between fingers, has a slick feeling.
Irrigate special crops	50 to 75	Tends to ball under pressure, but seldom will hold together.	Forms a ball, somewhat plastic, will sometimes slick slightly with pressure.	Forms a ball, will ribbon out between thumb and forefinger.
Irrigate	25 to 50	Still appears to be dry, will not form ball with pressure.	Somewhat crumbly, but will hold together from pressure.	Somewhat pliable, will ball under pressure.
	0 to 25	Dry, loose, single grained, flows through fingers.	Powdery, dry, sometimes slightly crusted, but easily breaks down into powdery condition.	Hard, baked, cracked and sometimes has loose crumbs on surface.

* Ball is formed by squeezing a handful of soil firmly.

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